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PROPULSION DIVISION

PROGRAM TITAN IIIM
STANDARD SPACE LAUNCH VEHICLE
DEVELOPMENT REPORT
FOR
STAGE I ENGINE DEMONSTRATION TESTING

Report 9180-941-DR-9 31 March 1969

AEROJET GENERAL

TITAN IIIM

STANDARD SPACE LAUNCH VEHICLE

DEVELOPMENT REPORT

For the

STAGE I ENGINE DEMONSTRATION TESTING

Report 9180-941-DR-9

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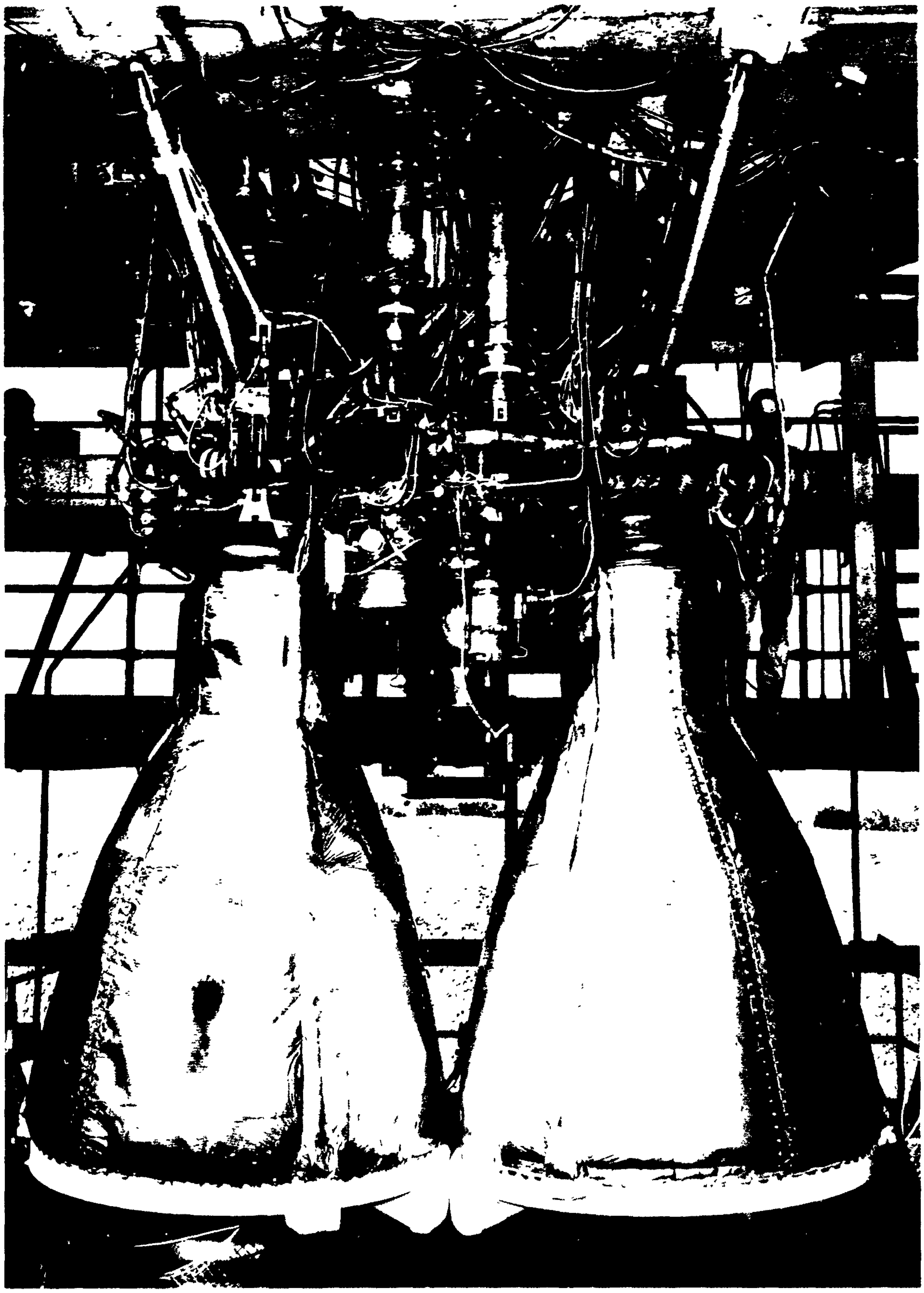

Figure 1 -- Demonstration Engine S/N 14

FOREWORD

This report is submitted in partial fulfillment of Line Item 29, Technical Reports, Contract Data Requirements List (CDRL) dated 2 October 1967, of Contract AF 04(695)-941, Program Titan IIIM, Standard Space Launch Vehicle.

The reports in this series cover the design and development of the Stage I and Stage II Titan IIIM engines and their components. The scope of this report is the demonstration testing of engines S/N 14 and S/N 15 in accordance with SSD-CR-65-8180-140 System Test Implementation Plan, Revision 2, dated 17 March 1967. Testing authorized by Contract Change Notifications and Change Orders which modified the plan by changing the engine configuration or altering the test conditions is also included.

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I. INTRODUCTION AND SUMMARY

The Titan IIIM Engine Modification Program was initiated in 1965 in order to increase the performance and improve the reliability of the Titan III core engine for use with the Air Force Manned Orbital Laboratory (MOL) Program. Development of the engine components was concluded by a Critical Design Review in September 1967. The redesigned engines were then submitted to demonstration testing from December 1967 to October 1968.

1.1 BACKGROUND AND REQUIREMENTS

Prior to the inception of the Titan IIIM Development Program the Titan I and Titan II missiles had a decade of successful service as an Air Force weapon system. Titan II vehicles had also been produced by the Air Force for NASA and had been used for launching the capsules in the highly successful Gemini Program. The Titan III, a modification to Titan II, employing auxiliary solid rockets for the boost phase and adding an additional stage called the transtage, was also in production for the Air Force Program 624A.

Titan III had originally been contemplated for use with MOL. However, as the program requirements became more clearly defined it became evident that substantial increases would be required in all performance aspects of the propulsion systems--increased thrust, higher combustion efficiency, and increased durability for extended operating duration. In addition, extra requirements for reliability, safety, and maintenance developed that had not been envisioned for Program 624A.

The primary performance requirements are given in Table 1:

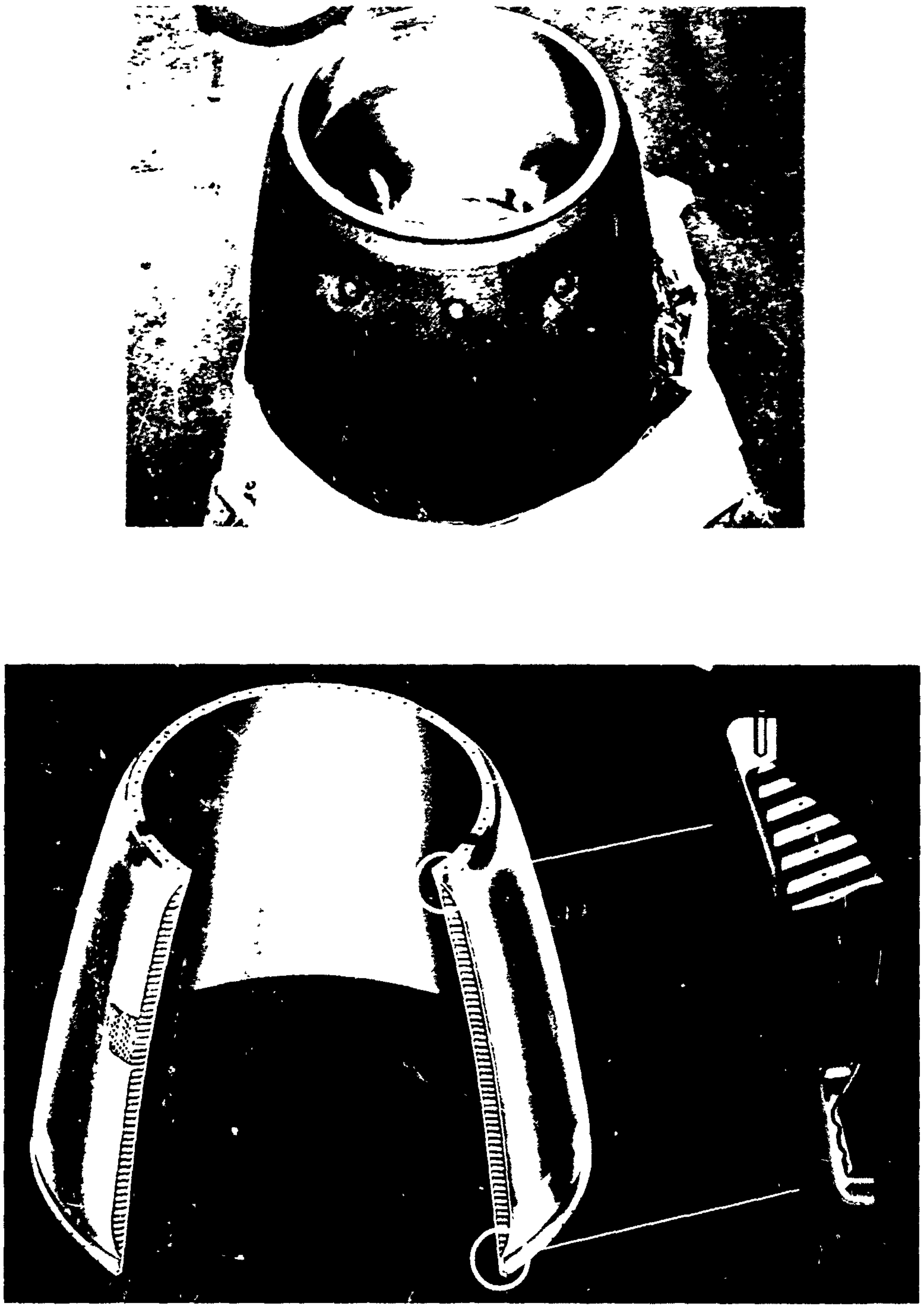


Figure 2 -- 15:1 Ablative Skirt

1.1, Background and Requirements (cont.)

Table 1--Primary Rocket Engine Performance Ratings

Parameter	Symbol	Dimension	Rocket Engine	Each Thrust Chamber Subassembly
Thrust,				
Nominal, Altitude	F	lb	520,000	260,000 ± 3%
Minimum Sea Level	F	lb	437,000	218,500
Specific Impulse, Steady State, Minimum (Altitude)	I_{sp}	lb-sec/lb	297.0	---
Mixture Ratio (Note 4)	MR	---	1.91 ± 2.0%	
Operating Cycle, Minimum	---	sec	200	200

Reference: CP-40224, Part I, Table IA

It was not necessary to change the basic Titan III propulsion system concept, but the major components required extensive redesign confirmed by testing, and the Stage I engine envelope had to be lengthened. The Stage I components affected are described in Section 2.1. A summary of their more outstanding features is given in Table 2.

Table 2--Titan IIIM Stage I Component Development

Component	New Design Features
Ablative Skirt (Figure 2)	New Item. Increased chamber area ratio to 15:1 with resulting increase in specific impulse.
Combustion Chamber (Figure 3)	Area ratio reduced from 8:1 to 6:1. Improved cooling. Improved strength in bending and resistance to side loads.

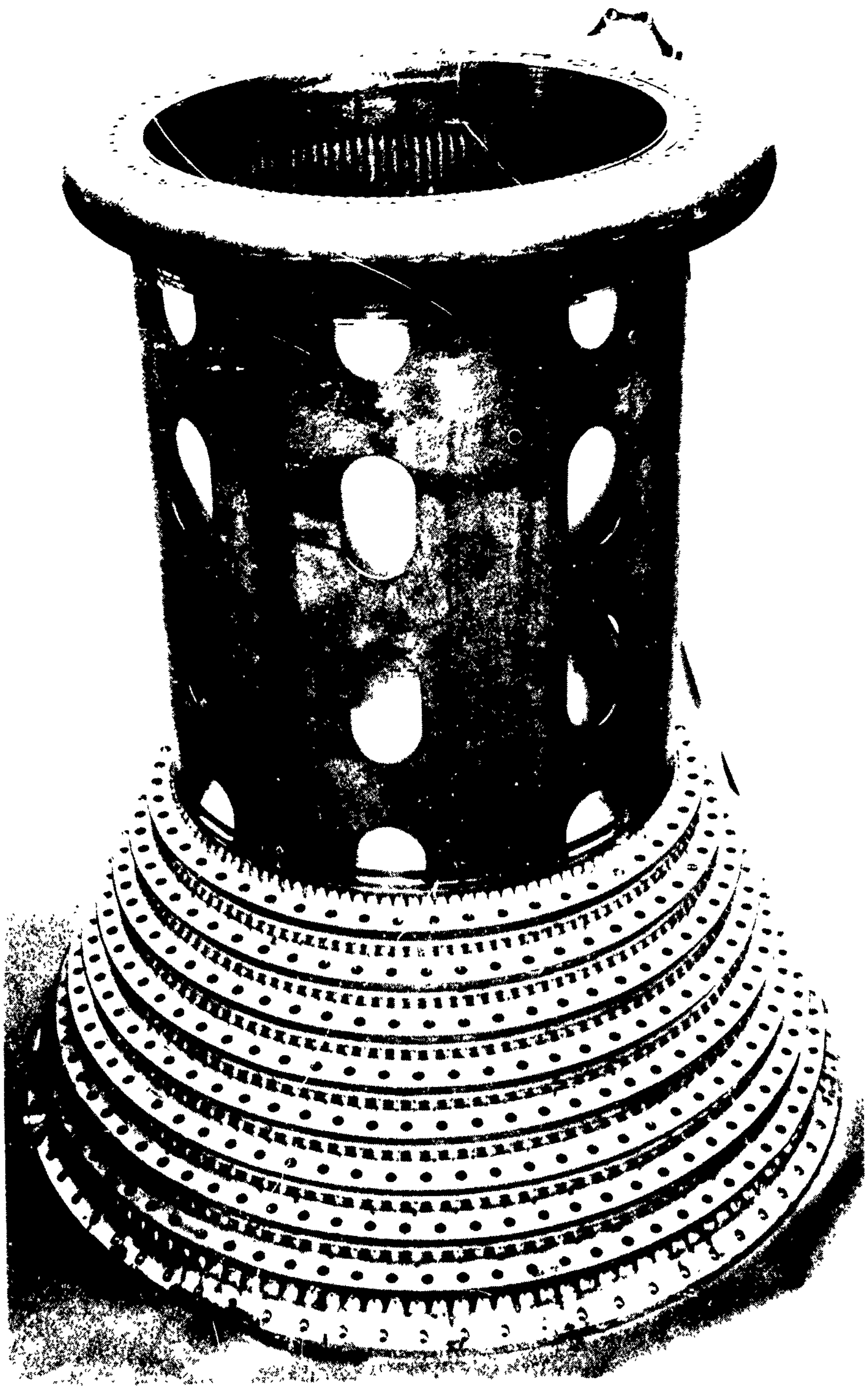


Figure 3 -- 6:1 Combustion Chamber

1.1, Background and Requirements (cont.)

Table 2--Titan IIIM Stage I Component Development (cont.)

Component	New Design Features
Injector (Figure 4)	New manifolding installed baffles for dynamic stability. Increased thrust-per-element, change to quadlet pattern for stability and performance.
Injector Clevis	Provision for redesigned Martin actuator.
Oxidizer Elbow (Figure 6)	Redesigned to eliminate cracked vanes.
Dome (Figure 7)	Increased strength.
Gimbal (Figure 8)	Increased strength for Titan IIIM loads.
Gearbox, High Speed Shaft (Figure 10)	Eliminated shaft resonance. Increase load capacity of bearings.
Gearbox, Lube System	Increased cooling capacity
Turbine Rotor (Figure 11)	Integral forging to reduce blade failure.
Thrust Chamber Pressure Switch	Redundancy for reliability and safety.
Gas Cooler	Hastalloy tubes to resist corrosion (Not demonstrated).
Exit Closure (Figure 13)	New item. Protects interior of chamber and skirt during Stage 0 flight.
Frame (Figure 14)	Increased strength for Titan IIIM loads. Provision for redesigned Martin actuators.

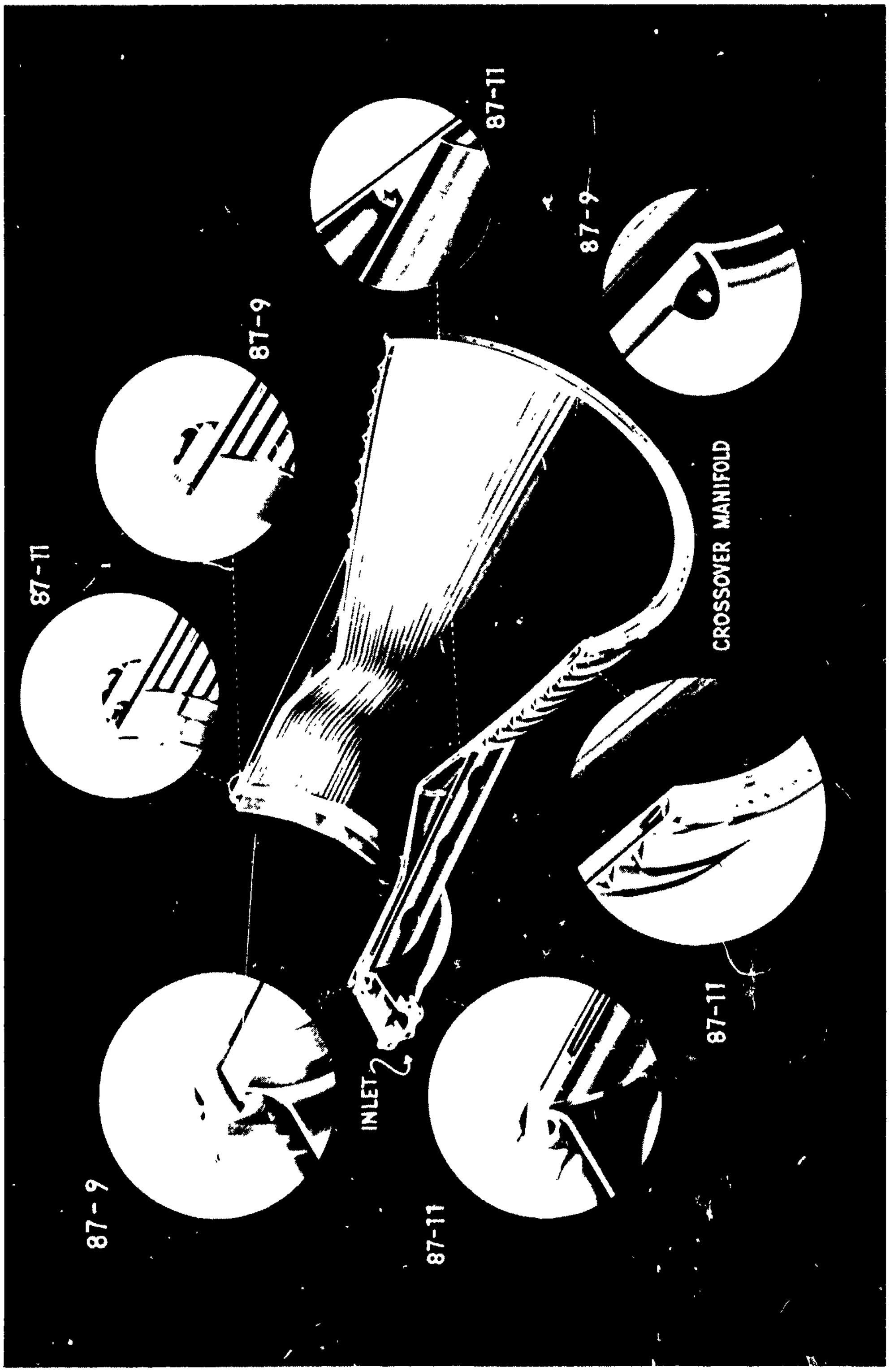


Figure 3 -- 6:1 Combustion Chamber--Design Details

1.1, Background and Requirements (cont.)

Besides the major items, minor design changes were made to other components, principally to enhance their reliability and to extend their operating life. These were straightforward drawing changes without need for development, either because they were already part of the general state of the art or because they had been developed on earlier programs.

The objective of the demonstration test program was to confirm the validity of the new component designs by engine tests at both nominal and extreme Titan IIIM operating conditions without unnecessarily repeating the Titan II and Titan III qualification tests. The test program also served as a convenient vehicle for testing related items, not intrinsic to the engine system, such as the Martin POGO accumulators, gimbal actuators, flight instrumentation, and ground equipment. The planned program consisted of 30 tests, 15 on each of two engines including:

- 5 full duration tests at nominal conditions to demonstrate performance
- 1 full duration test at extreme suction head conditions
- 4 full duration tests at the most adverse conditions for the thrust chamber and ablative skirt predicted from scheduled flight trajectories.
- 5 adjustment tests of 20 sec duration

No special tests were scheduled strictly for the purpose of demonstrating reliability, personnel and system safety, maintainability, or other system requirements. However, the procedures and documentation described in SSD-CR-65-8180-170, System Effectiveness Implementation Plan, were observed throughout the demonstration tests.

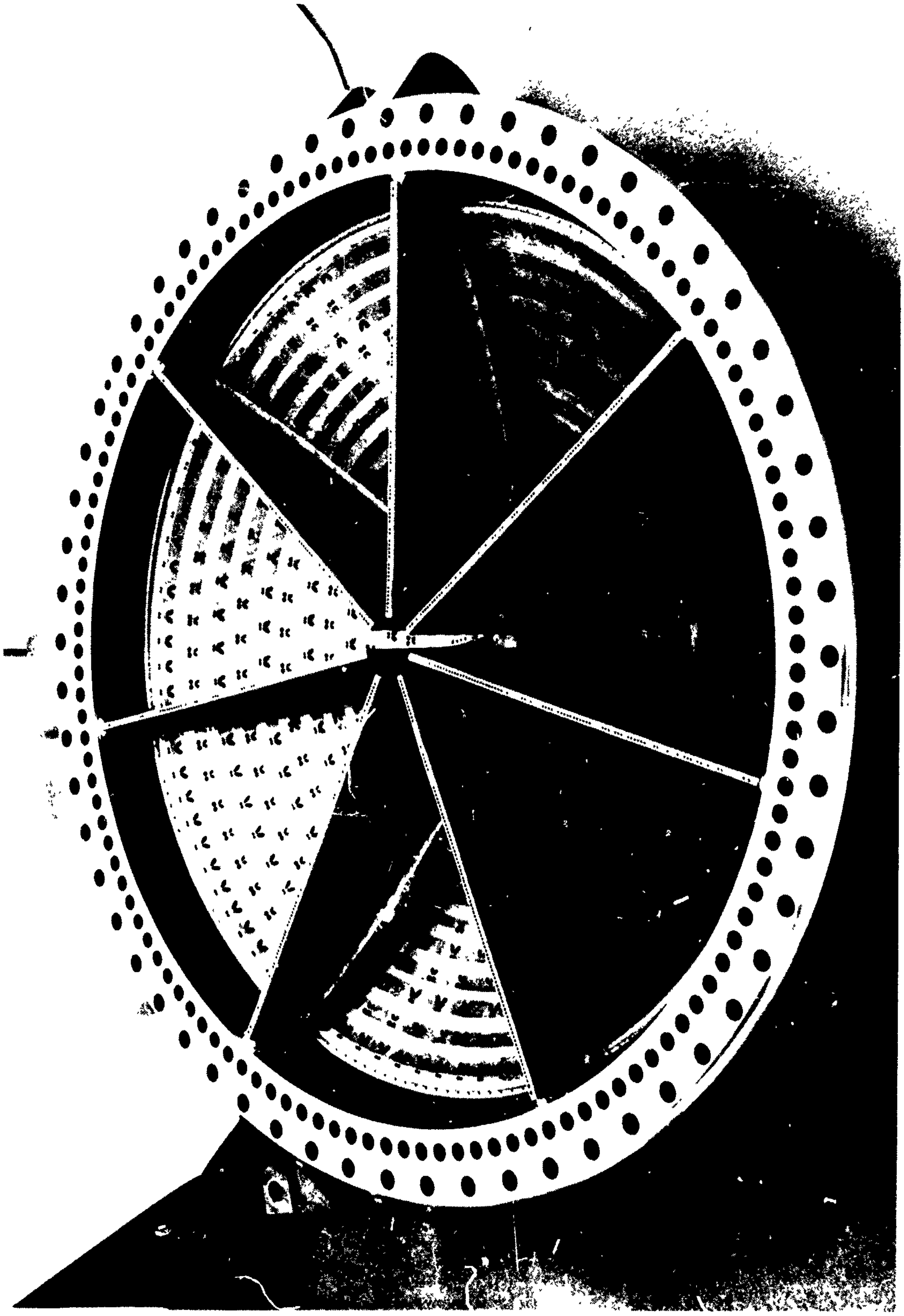


Figure 4 -- Baffled Injector

1, Introduction and Summary (cont.)

1.2 CONTRACTUAL DATA

The demonstration test program was conducted in compliance with SSD-CR-65-8180-120, Engineering Implementation Plan, Revision 2, and SSD-CR-65-8180-140, System Test Implementation Plan, Revision 2, and the Statement of Work, Contract AF 04(695)-941. Revisions to these plans are listed below. The paragraphs applicable to the demonstration tests are shown in Appendix A.

CCN/CO No.	Description
SA 6	Phase II Titan IIIM Program
CO 17	Replace lube oil cooler
CO 19	Replace combustion chamber S/N 20 with S/N 17
CO 20	Replace lube oil coolers
CO 23	Rework RD-14 baffle 3, revise Demo test requirements table, SSD-CR-65-8180-140, repair TPA S/N 10
CO 28	Replace fuel bootstrap line, RD-15, install combustion chamber S/N 92, RD-14
CO 30	Revise Demo test requirements table
CCN 74	Turbine Rotor Program
CCN 90	Turbine 2nd Nozzle Program
CCN 91	Incorporate various flight configuration components
CCN 93	Replace hot gas cooler
CO 117	Exit closure development
CO 119	Install low pressure drop GGFCV in SA #1 and an orifice in the gas generator fuel feed circuit of SA #2, RD-14. Revise performance requirements of 15th test, RD-14
CO 120	Replace RD-15 turbine rotors
CO 124	Replace and repair turbopump assembly, RD-15
CO 139	POGO

1.3 SPECIFICATIONS AND DOCUMENTATION

The basic engine specification is Contract End Item Specification CP-40224A, Engine, Rocket, Liquid Propellant, YLR87-AJ-11, Part I and Part II. Other end item specifications covering components tested with the engine are:

CP-40228A Extension Kit (Ablative Skirt), Thrust Chamber, YLR87-AJ-11, Rocket Engine Subassembly

CP-40246A, Exit Closure Assembly, YLR87-AJ-11

AGC-40209, Instrumentation Kits, Telemetry, LR87-AJ-9 and LR87-AJ-11.

AGC-40189, Installation Kit, Turbine Starter Cartridge, YLR87-AJ-9

Also governing are the following Engineering Critical Component Specifications:

EC-42371A, Thrust Chamber Assembly, YLR87-AJ-11

EC-42373A, Turbopump Assembly, YLR87-AJ-11

EC-42375A, Gas Generator Assembly, YLR87-AJ-11

EC-42379A, Frame, Rocket Engine, YLR87-AJ-11

Inspection reports covering all hardware installation, removal and repair, with discrepancies noted, are on file at AGC and will be issued in a separate report. Reports of failure investigations will also be included.

Preliminary reports 9180-941-DR-9P-1 and P-2 were issued covering the testing of engines S/N 14 and S/N 15, respectively, at the time of the hardware displays.

The following technical reports describe the design, development, and performance of the major redesigned Stage I engine components:

1.3, Specifications and Documentation (cont.)

9180-941-DR-1, Stage I Engine Frame and Stiff Link
9180-941-DR-2, Stage I 15:1 Ablative Skirt
9180-941-DR-3, Stage I 6:1 Combustion Chamber
9180-941-DR-4, Stage I Redesigned Minor Engine Components
9180-941-DR-5, Stage I Baffled Injector
9180-941-DR-7, Stage I Turbopump Assembly
9180-941-DR-8, Titan IIIM TCA Performance Analysis Development
9180-941-DR-11, POGO (Series of 5 reports)
9180-941-DR-12, Stage I Thrust Chamber Exit Closure

Design and development of the Stage I engine components and engine development testing at the subassembly level are also documented in the Monthly Program Progress Reports 8180-212-MR-1 through -MR-6 (Phase I) and 9180-941-MR-1 through -MR-35 (Phase II).

1, Introduction and Summary (cont.)

1.4 SUMMARY OF TESTING

The Titan IIIM engine demonstration test program commenced 20 December 1967 with the first test of engine S/N 14 and was completed 17 October 1968 with the last test of engine S/N 15.

Of the 31 tests conducted, there were 30 valid tests achieving all primary objectives. A malfunction occurred during one test on engine S/N 15, resulting in failure to complete the starting cycle. The classification of the tests was: 11 adjustment tests, 9 performance evaluation tests, 8 peripheral evaluation tests, 2 net positive suction head evaluation tests and 1 malfunctioned test. In addition, thrust chamber gimballing with ablative skirts and Refrasil insulation panels was conducted concurrently on six of the tests.

In addition to the basic program requirements, ancillary and supplemental test objectives were incorporated on some tests and are discussed in Sections 5 and 6.

1.4.1 Engine S/N 14 Testing

The demonstration testing of engine S/N 14 commenced 20 December 1967 and was completed 27 August 1968. Fifteen tests were conducted for a cumulative duration of 1844.9 sec. Thrust chamber gimballing was conducted during three of the tests using 15:1 ablative skirts and Refrasil insulation panels. One test was conducted with 12:1 ablative skirts, modified Refrasil panels and The Martin Company 10-sq in. gimbal actuators; however, gimballing was not performed.

All tests achieved their scheduled duration and objectives with one exception: one test, scheduled for 200 sec duration, was terminated at 115 sec.

1.4, Summary of Testing (cont.)

The premature shutdown was caused by failure of a turbine rotor, a component that antedated the demonstration engine configuration and was not under development at that time.

POGO fuel accumulators (Change Order 125) were tested on three occasions and assorted flight instrumentation components were tested six times. The last peripheral test was conducted with a low pressure drop fuel check valve in Subassembly 1 and an orifice for suppressing fuel venturi cavitation in Subassembly 2 in order to evaluate the effect upon generator system performance.

Damage to components, excluding the rotor failure, sustained during the tests did not adversely affect the operation or performance of the engine. The damages most frequently incurred were injector base weld cracks and combustion chamber leakages and cracks.

1.4.2 Engine S/N 15 Testing

The demonstration testing of engine S/N 15 commenced 3 June 1968 and was completed 17 October 1968. Sixteen tests were conducted for a cumulative duration of 2114.7 sec. Thrust chamber gimballing was conducted on three of the tests where 15:1 ablative nozzle extensions and Refrasil insulation panels were installed on the engine. The last test of the series employed ablative skirts fabricated at the Aerojet-General facility. The 16 tests consisted of five adjustment tests; six performance evaluation tests, including one malfunction, one net positive suction head test; and four peripheral evaluation tests. Fifteen tests were satisfactory and the scheduled durations were achieved. One test was unsatisfactory: an engine subassembly failed to start.

In addition to the basic program requirements, there were supplemental test objectives for selected tests. POGO fuel accumulators (Change Order 125) were installed before conducting four of the peripheral tests. Expulsion tests

1.4, Summary of Testing (cont.)

were conducted with four exit closures (CCN 44) prior to two of the engine tests and two flight instrumentation pressure transducers (CCN 91) were each installed for five engine tests.

On one occasion, a pressure sequence valve failed to return to the de-energized position following shutdown. This prevented opening of the thrust chamber valves on that subassembly at the start of the succeeding test. Since the start transient was completed by only one subassembly, the test was terminated. The subsequent investigation disclosed that the solenoid valve plunger had seized because of contamination, preventing actuation of the thrust chamber valves.

Following the test to demonstrate operation at low net positive suction (NPSH) both subassembly oxidizer pump seals leaked but not enough to require replacement. Three more tests were conducted successfully without intervening corrective action.* Investigation verified the damage to the seals and both were replaced prior to the next test. Inspection of films following a fire noted during the last test of the series disclosed leakage from one fuel pump seal; the leakage was later verified by leak check and visual examination. Turbine seal leakage which exceeded the specification limits occurred on two tests. The first occurrence was corrected by rework of the seal. No rework was attempted after the second occurrence and the leakage did not appear on any of the subsequent tests.

Cracks developed in the base welds of baffles on both injectors during the first five tests. Repairs incorporating the current procedures for preparation and welding were made and eight consecutive tests were conducted before a single small crack appeared in each injector. After each of the three remaining tests the number of base weld cracks were found to have increased

*It was permissible to replace turbopump seals, without penalty, when excessive leakage was detected during prefire checks.

1.4, Summary of Testing (cont.)

and the previous cracks were longer; however, both injectors were still suitable for continued testing without additional repairs.

Combustion chamber leakage at the inside tube-to-flange joints appeared on early tests and prevailed throughout the test series. The leakage during early tests was too slight to measure; it progressed somewhat thereafter but never approached proportions sufficient to affect performance or operation of either unit.

Cracks were noted on the lower weld seam on the shell of one combustion chamber prior to the last test. Repairs were readily made and the chamber approved for retest.

1.4.3 Summation of Test Results

Engine Performance

The nominal performance phase of the demonstration program consisted of nine valid tests (excluding adjustment tests) to evaluate mixture ratio repeatability, thrust growth characteristics, autogenous pressurization system performance, thrust capability, and specific impulse in addition to verifying that the engine performance was compatible with the requirements specified in Paragraph 3.1 of the Contract End Item Specification.

The peripheral test phase of the demonstration program consisted of 10 valid tests, excluding adjustment tests, to determine engine operating capability at worst flight conditions for the ablative skirts and combustion chambers. Included were two tests operated at minimum net positive suction head profiles.

1.4, Summary of Testing (cont.)

Supplementary Evaluations

Additional hardware, contractually authorized, was utilized on selected tests to provide evaluation data and information beyond the basic program requirements. These additional items included POGO fuel accumulators (used on eight tests per CO 125), two exit closures (expulsion tests per CCN 44), 12:1 ablative skirts, Martin-supplied 10 in.-sq actuators (CCN 53), and flight instrumentation pressure transmitters (CCN 91). The 12:1 ablative skirts were extensively damaged during the postfire heat soak period.

One test with a low pressure drop fuel check-valve on one gas generator assembly and a test with an orifice in one gas generator fuel bootstrap circuit to suppress venturi cavitation were made on a noninterference basis to obtain supplemental data. There were also inspections of lube oil pump snap rings and evaluations of turbine manifold leak check procedures.

1.4.4 Hardware Evaluations

There were no significant discrepancies associated with the improved Titan IIIM components. However, there were failures of two other components that did adversely affect their respective tests.

One test of engine S/N 14 was terminated at 115 sec when a TPA turbine rotor failed. Failure was caused by separation of the turbine buckets. The rotor was of a superseded design, for interim use only until the Titan IIIM prototype rotors were available.

One test of engine S/N 15 was terminated during the start phase when the thrust chamber valves of one subassembly failed to open. Investigation disclosed that contamination in the override solenoid in the sequence valve had caused it to stick in the energized position.

1.4, Summary of Testing (cont.)

Frequent incidents of cracks in the base welds of injector baffles were experienced early in the program. The primary cause for the cracks was the preparation and weld procedures existing at the time that the injectors were originally fabricated. Subsequent repairs using current procedures extended the weld integrity to eight tests before a single crack appeared.

Combustion chamber leakage occurred frequently at the forward flange-to-tube joint but was generally not great enough to measure. Although the leakage was noted to have increased after each succeeding test, there was never sufficient quantity to affect operation or performance.

A small number of cracks was noted in the terminal point of the lower weld joint of three combustion chamber shells. A metallurgical analysis concluded that the fracture initiated in fatigue and rapid rupture followed by cleavage in the tensile mode. Improved weld procedures will minimize crack recurrence.

Gross oxidizer pump seal leakage was noted on both TPAs following the NPSH test of engine S/N 15. Three additional tests were conducted before replacing the seals. Because the usual maintenance was not performed, entry of oxidizer into the gearbox initiated corrosion on some parts and required their replacement.

Fuel pump seal leakage occurred during the last test of engine S/N 15. Disassembly and investigation disclosed a crack in the seal bellows. The seal had accumulated 2120 sec time and 16 test cycles.

One rotor bolt was found to have lost all preload (torque) following an early test of engine S/N 14. There was no adverse affect detected in the test data or by subsequent inspections.

1.4, Summary of Testing (cont.)

Two corroded bearing assemblies were found in one TPA gearbox during the post program final disassembly. These bearings were on the same fuel pump that seal leakage occurred.

The final disassembly of the thrust chamber valves disclosed cracked lipseals in both oxidizer valves. On one seal approximately 30% of the cracking was all the way through the material, one bearing liner material was loose and there was minor galling on all valve bearings.

1, Introduction and Summary (cont.)

1.5 CONCLUSIONS AND RECOMMENDATIONS

The Titan IIIM engines S/N 14 and S/N 15 have successfully demonstrated the performance repeatability requirements and operational capabilities as described in the System Test Implementation Plan, SSD-CR-65-8180-140, Revision 2 and subsequent directions.

a. The design integrity of the T-IIIM improved components is substantiated by the absence of any associated failures or significant discrepancies during any one test. The hardware damage sustained during the program was not sufficient to impair the success of any test.

b. The supplemental evaluation test objectives were satisfactorily achieved.

c. The two significant failures, turbine rotor and override solenoid, were not directly associated with the primary objective of demonstrating Titan IIIM component improvements. The rotor which failed was not of suitable design and was later replaced with the Titan IIIM rotor that demonstrated its superiority in subsequent testing. The override solenoid failure caused by contamination was a random occurrence but was of such significance that action has been taken to eliminate the contaminant source.

d. The frequency and number of injector baffle weld cracks were the result of insufficient weld penetration. Improved procedures which reduced the discrepancy incidences rate were implemented successfully.

e. Leakage at the combustion chamber forward flange tube joints was the result of non-uniform tube fit up and subsequent irregular brazing that separated under repeated pressure and temperature cycling. Changes made to the tube forming and brazing procedures have substantially reduced the incidents of leakage.

1.5, Conclusions and Recommendations (cont.)

f. The conclusion from a metallurgical analysis of a combustion chamber shell weld crack was that the fractures initiated in fatigue in the terminal weld crater. A revised welding procedure which includes backwelding the weld terminus has been implemented and has eliminated the aforementioned discrepancy.

g. Failure of the TPA oxidizer pump seals during one NPSH test is attributed to the severe cyclic loading induced by extremely low NPSH operation. During the three successive tests, before seal repairs were made, oxidizer entered the gearbox initiating corrosion on some parts which required replacement. The discrepancy noted is a function of the extremely rare environment and requires no corrective action.

h. The crack in the fuel pump seal bellows was caused by cyclic flexing of the bellows over extended durations of repeated tests, resulting in fatigue. The material structure was satisfactory. No correction is required.

i. Preload loss on the turbine rotor bolt was caused most likely by improper preloading during the previous assembly. There was no adverse affect detected in the test data or from subsequent inspections. No correction was required.

j. Corrosion of the two TPA bearing assemblies was believed to have been incurred subsequent to testing since the corrosion which occurred on mating rotational surfaces was not disturbed as would be expected from loading. These were on the same fuel pump shaft where seal leakage occurred; therefore it is concluded that either fuel or cleaning neutralizer entered the gearbox and initiated corrosion.

1.5, Conclusions and Recommendations (cont.)

k. Cracking of the oxidizer valve lipseals is attributed to low strength of the material as indicated by hardness values below the blueprint minimum allowable values. The low hardness of the material suggests incomplete annealing; thus the seals would retain relatively high internal stresses. Action has been taken which will result in hardness checks of seals prior to valve fabrication.

l. The galling of the thrust chamber valve bearings has been a frequent occurrence and is the result of insufficient clearance between the valve gates and bearing ends. Valve assembly procedures have been improved to ensure adequate clearance in accordance with the blueprint.

m. The loose bearing liner was probably caused by insufficient lubricant. This is considered a random occurrence as evidenced by a low incidence rate.

n. On the basis of the above considerations it is recommended that the Titan IIIM Stage I engine be committed to production and flight.

2. Testing

   2.1 Description of Engine

   2.2 Test Objectives

   2.3 Test Plan

   2.4 Test Setup and Operation

   2.5 Narrative of Testing

2. TESTING

The Titan IIIM Engine Demonstration Test Program consisted of 30 sea-level tests, 15 each on two engines, S/N 14 and S/N 15. The engines were Titan IIIM Stage I prototype, Model YLR87-AJ-11, as described in Specification CP-40224A, and fabricated and assembled in accordance with the Controlled Engineering Parts List, first issued May 1967 and revised monthly. Testing was initiated 20 December 1967 and completed 17 October 1967. Formal hardware displays and review of test procedures and data were held for each engine after it had completed its series of tests.

2.1 DESCRIPTION OF ENGINE

The baseline for the Titan IIIM engine, Model YLR87-AJ-11 shown in Figure 5, is the Titan IIIC engine, Model LR87-AJ-9, SN 1019. The Titan IIIM configuration was obtained by redesigning, substituting, or adding individual components to the baseline, while retaining in general their same functional relationships and the same engine operating sequence and firing procedures.

The modifications to the components are given in detail in SSD-CR-65-8180-120, Engineering Implementation Plan, Section II, pp 34-103. It is unnecessarily redundant to repeat the plan in full; instead a summary is provided for each component, listing the problem areas, the design solution, and the development plan and results.

2.1.1 Stage I Thrust Chamber Assembly

In order to meet the Titan IIIM requirement for 520,000 lb engine thrust at altitude, together with increased sea level thrust, it was necessary to redesign the thrust chamber assembly to operate at higher chamber pressure and larger expansion ratio. This in turn increased the loads on the combustion chamber, the injector dome and the gimbal. Consideration of reliability and safety also caused extensive redesign of the injector, oxidizer elbow, and injector to chamber seals. The yaw clevis was modified to fit the new Martin gimbal actuators.

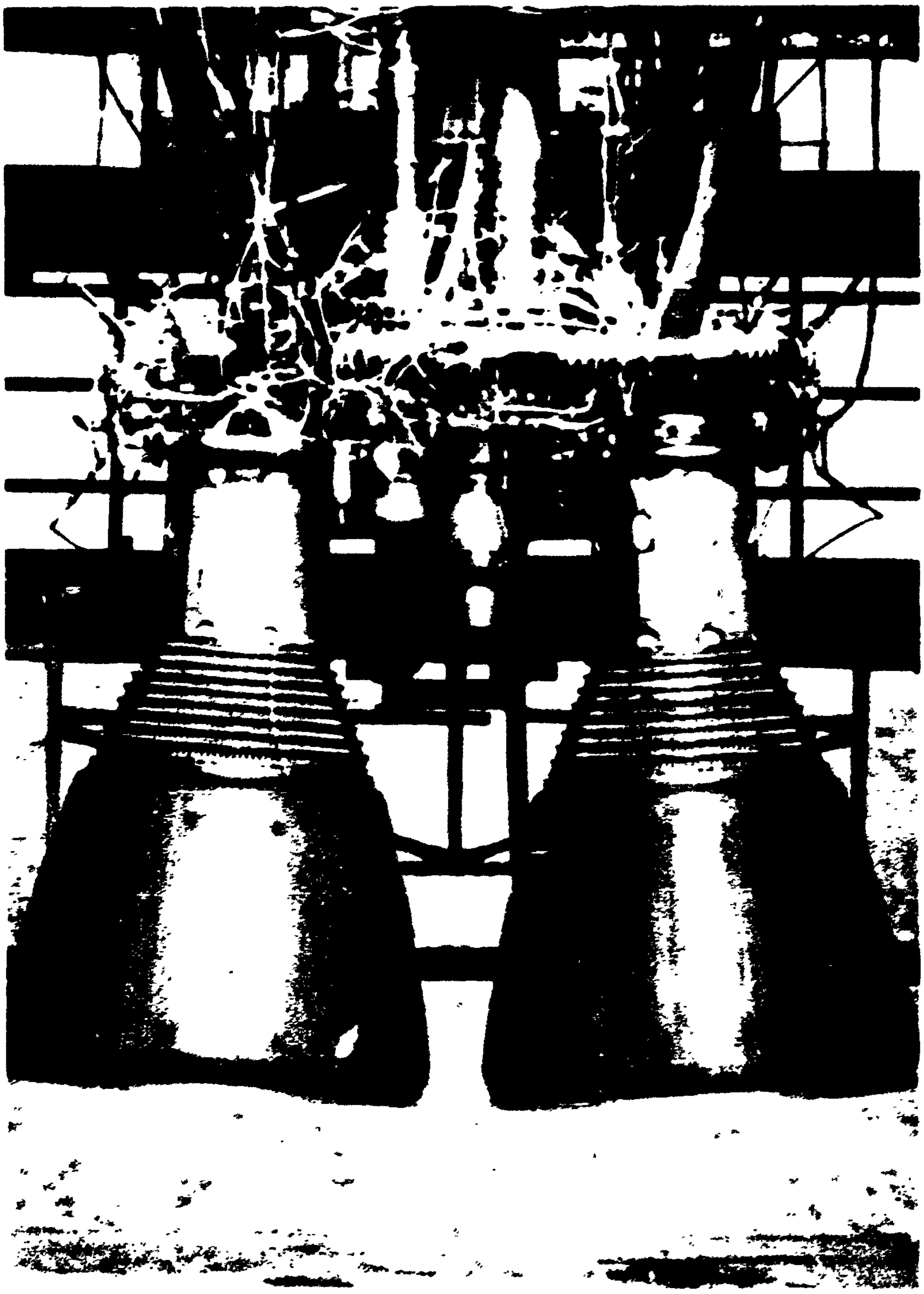


Figure 5 -- Demonstration Engine S/N 15, Prefire

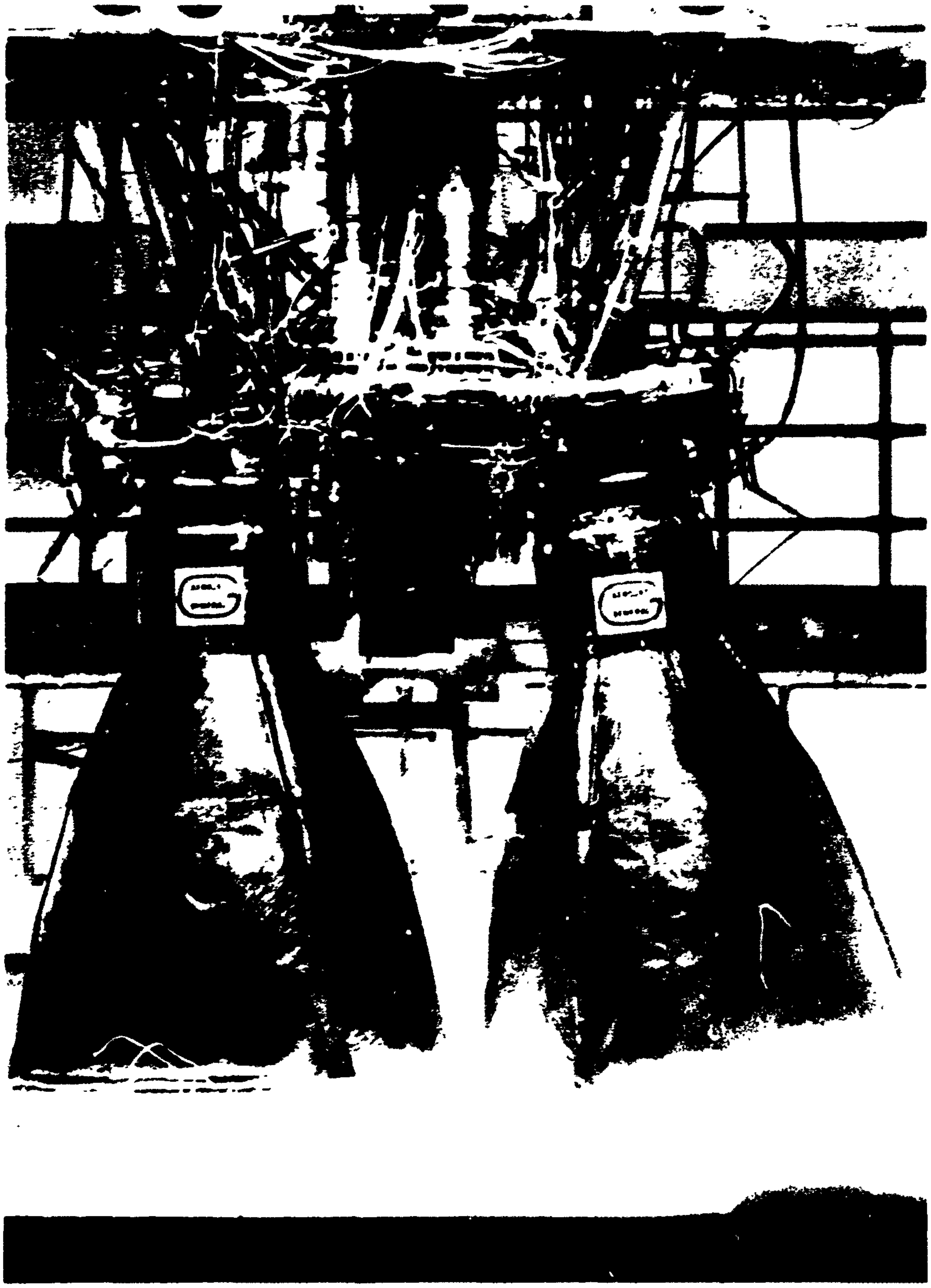


Figure 5 -- Demonstration Engine S/N 15, Firing

2.1, Description of Engine (cont.)

Ablative Skirt

The requirement for increased thrust at altitude was met by increasing the nozzle exit area in order to permit the exhaust gases to expand and accelerate further before leaving the nozzle exit. This was provided by an ablative nozzle extension (skirt), shown in Figure 2, which increased the exit-to-throat area ratio from 8:1 to 15:1. The skirt was attached to the combustion chamber by a bolted flange at the 6:1 area ratio plane, with corresponding shortening of the chamber. The skirt is composed of a laminated silica-phenolic liner supported by a honeycomb structure with an outer cover. A mounting flange was provided at the exit for supporting a protective closure. The liner was contoured for optimum expansion of the chamber gases.

Eighteen skirts of this design were submitted to a total of 53 tests during development, including ten tests of 200 sec duration or more. There were no failures.

Combustion Chamber

Addition of the ablative skirt permitted shortening the regeneratively cooled combustion chamber to 6:1 area ratio. By shortening the path of the cooling fluid and tailoring the cross-sectional area of the coolant tubes, it was possible to increase its velocity at the same pressure differential. The increased coolant velocity lowers the burnout heat flux ratio (R_{BO}): flux at the chamber wall divided by the flux resulting in burnout.

The significant differences that distinguish the Titan IIIM chamber, shown in Figure 3, from its predecessor are:

2.1, Description of Engine (cont.)

a. One hundred and twenty-eight double tapered tubes with thicker walls and no bifurcations in the divergent portion of the nozzle. The taper of the tubes was designed to provide nearly equal burnout ratios throughout their length. The design ratio in all areas was less than 0.82.

b. A reinforcing shell extending from the inlet torus to the 2.2:1 area ratio in the divergent section. The shell supports the nozzle throat against the severe side loads induced during the start transient and during gimballing of the thrust chamber.

c. Redesign of the inlet distribution manifold (torus) to reduce pressure drop and to provide more uniform flow distribution in the coolant tubes by improving the turning angles.

d. Provision of a mounting flange for the ablative skirt. This also afforded opportunity to reduce the hydraulic losses and improve the flow distribution at the aft collector ring ("turnaround flange").

e. Structural and hydraulic redesign of the injector-to-chamber mounting flange to decrease thermal distortion and to minimize pressure loss.

Besides development testing, the redesigned chamber as described above underwent 37 design verification tests successfully prior to the start of engine demonstration. Heat transfer data indicated that the burnout heat flux ratio was below the 0.82 design limit on all tests for which data were obtained.

Injector

The Stage I injector was redesigned in order to assure stable combustion throughout the engine operating cycle. Statistically, the Titan II, Stage I, injector had an extremely high record of success, but pulse tests

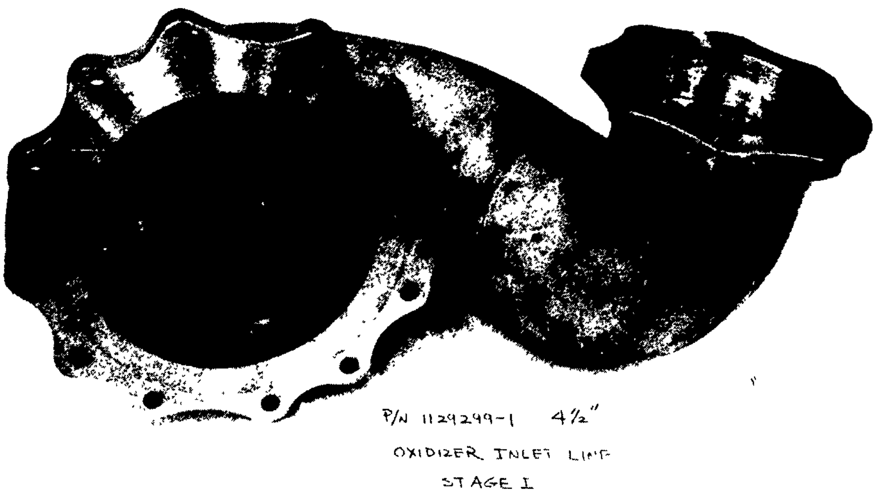


Figure 6 -- Oxidizer Inlet Line

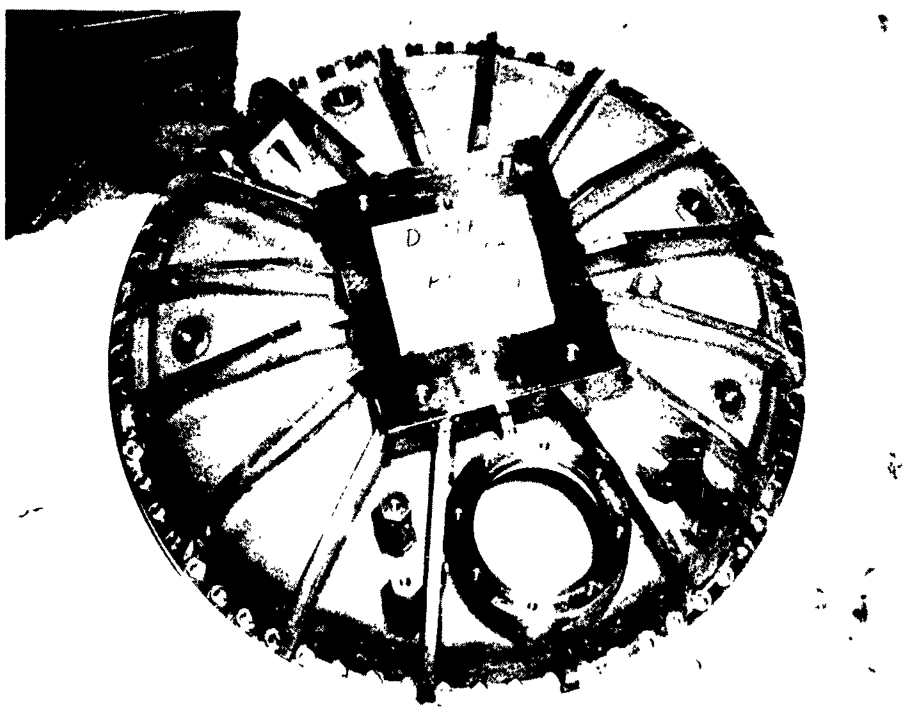


Figure 7 -- Injector Dome

2.1, Description of Engine (cont.)

had demonstrated that the injector would permit unstable combustion when perturbed. Design changes had to be accomplished without decreasing the specific impulse.

The principal characteristics of the redesigned injector (see Figure 4) are a 450-lb-per-element quadlet injection pattern and a seven-blade radial baffle. Hydraulic analysis and testing made possible a more uniform injection matrix than that exhibited by previous Titan designs, which contributed to maximizing performance. The baffle was protected from the heat of the combustion gases by fuel film cooling on the external surfaces and internal oxidizer flow which was sprayed from the baffle tip. Because of the improved cooling characteristics of the combustion chamber, it was possible to reduce the chamber film cooling to 10.5%.

The Stage I injector had undergone 54 engine subassembly tests and 37 design verification tests in addition to development testing prior to the start of engine demonstration. During the development testing, it had exhibited the ability to sustain stable combustion when perturbed by pulse changes as high as 400 grains (tangential) and 200 grains (nondirected). The specific impulse of the injector was slightly higher than the previous Titan III model.

<u>Oxidizer Inlet Line</u> (See Figure 6)

Throughout the production history of Titan II, Gemini, and Program 624A, the Stage I oxidizer inlet line (elbow) had experienced cracks where the flow guide-vanes attached to the elbow.

The problem was corrected for Titan IIIM by providing a large radius, smooth contour elbow that required no vanes to maintain smooth flow. The elbow had been tested successfully on the experimental engine subassembly prior to the start of engine demonstration.

Figure 8 -- Gimbal Block

2.1, Description of Engine (cont.)

In conjunction with this effort a divergent taper had been incorporated in the inlet duct to the oxidizer dome to maintain the streamlines. This change reduced the velocity of the fluid at the inlet and produced more uniform flow distribution in the oxidizer injector.

Oxidizer Dome (See Figure 7)

The oxidizer injector dome had been a composite welded structure, finished by machining. This article was not sufficiently strong to sustain Titan IIIM loads. A dome of greater strength was designed to be machined from a forging and this design was incorporated in the demonstration engines.

Injector-to-Chamber Seals

The improved RACO seal grooves for the injector-dome-chamber interface developed during the AEIP program were incorporated in the Titan IIIM engine without further development. A subsequent Raco seal modification was tested (see Section 3.3), but it was not recommended for use on production engines.

Gimbal (See Figure 8)

The increase in thrust for Titan IIIM together with the enlarged gimbal angle made it necessary to strengthen the gimbal bearings and races. The new design was submitted to a successful static proof test, following which it was incorporated in the demonstration engines.

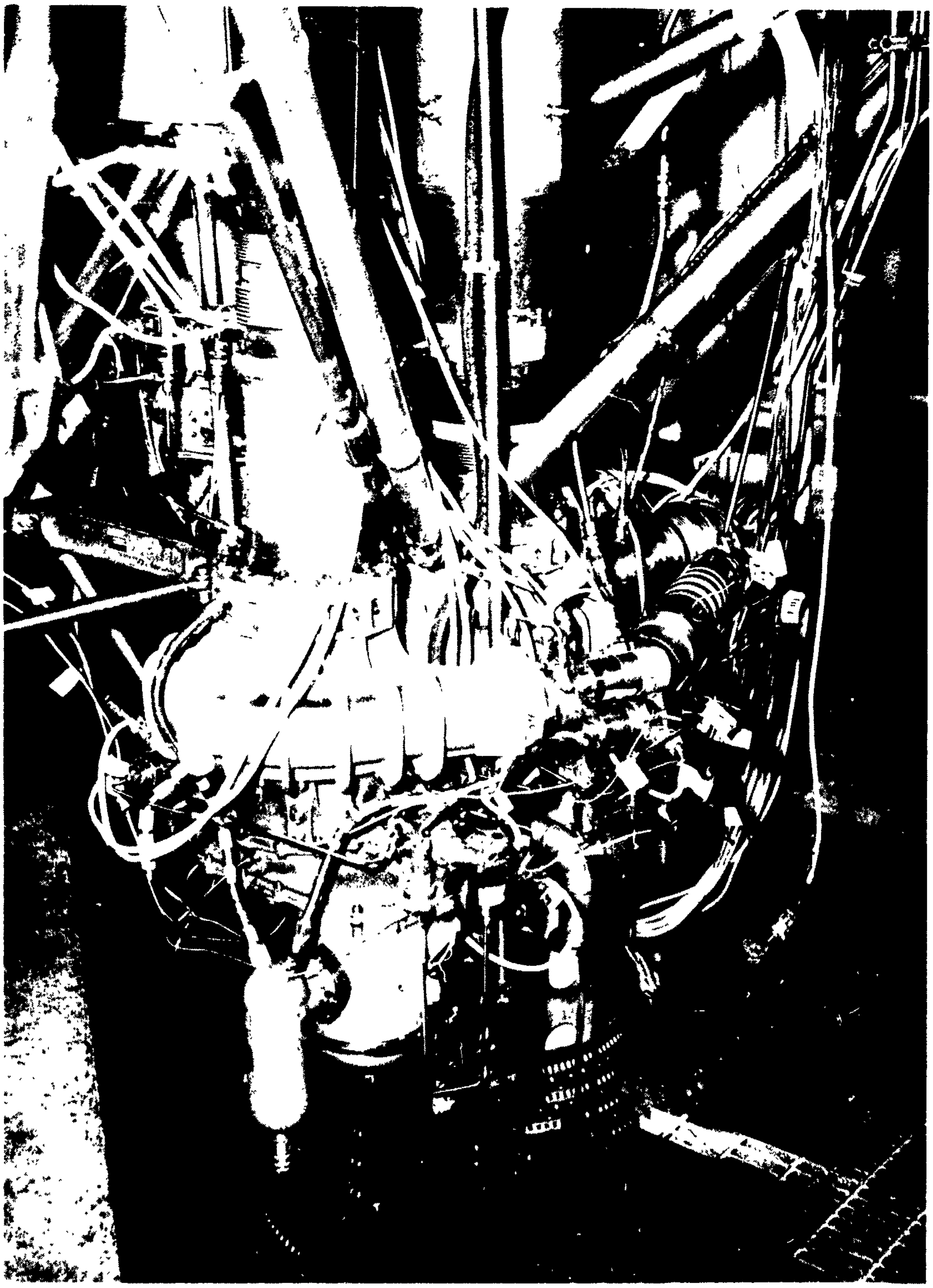


Figure 9 -- Stage I Turbopump

2.1, Description of Engine (cont.)

Injector Yaw Clevis

The injector yaw clevis was lengthened to provided clearance for the redesigned gimbal actuators supplied by The Martin Company. No development was required prior to demonstration testing.

2.1.2 Turbopumps (Figure 9)

The principal development activity concentrated on enhancing the reliability and extending the operating life of the gearbox. The areas of concern were the high speed shaft and the lubrication system.

While development was in process, blade failures were encountered in the rotors of the first turbine stage on both the Titan IIIB production and on the Titan IIIM experimental turbopumps. This led to redesign of the rotors. The most significant design change took place in the first turbine rotor. Only minor changes were made to the second rotor.

Other improvements demonstrated during the AEIP program were incorporated without further development.

High Speed Shaft (Figure 10)

The Stage I gearbox had exhibited a marginal load carrying capacity in the lower (B-6) high speed bearing, which had exhibited rapid temperature rise rates and random failures caused by overloading. This required redesign of the high speed shaft and associated bearings.

The principal features of the new design were:

a. The high speed shaft was stiffened in the areas of maximum bending to ensure that the critical speed was higher than any operating transient, thereby avoiding resonance.

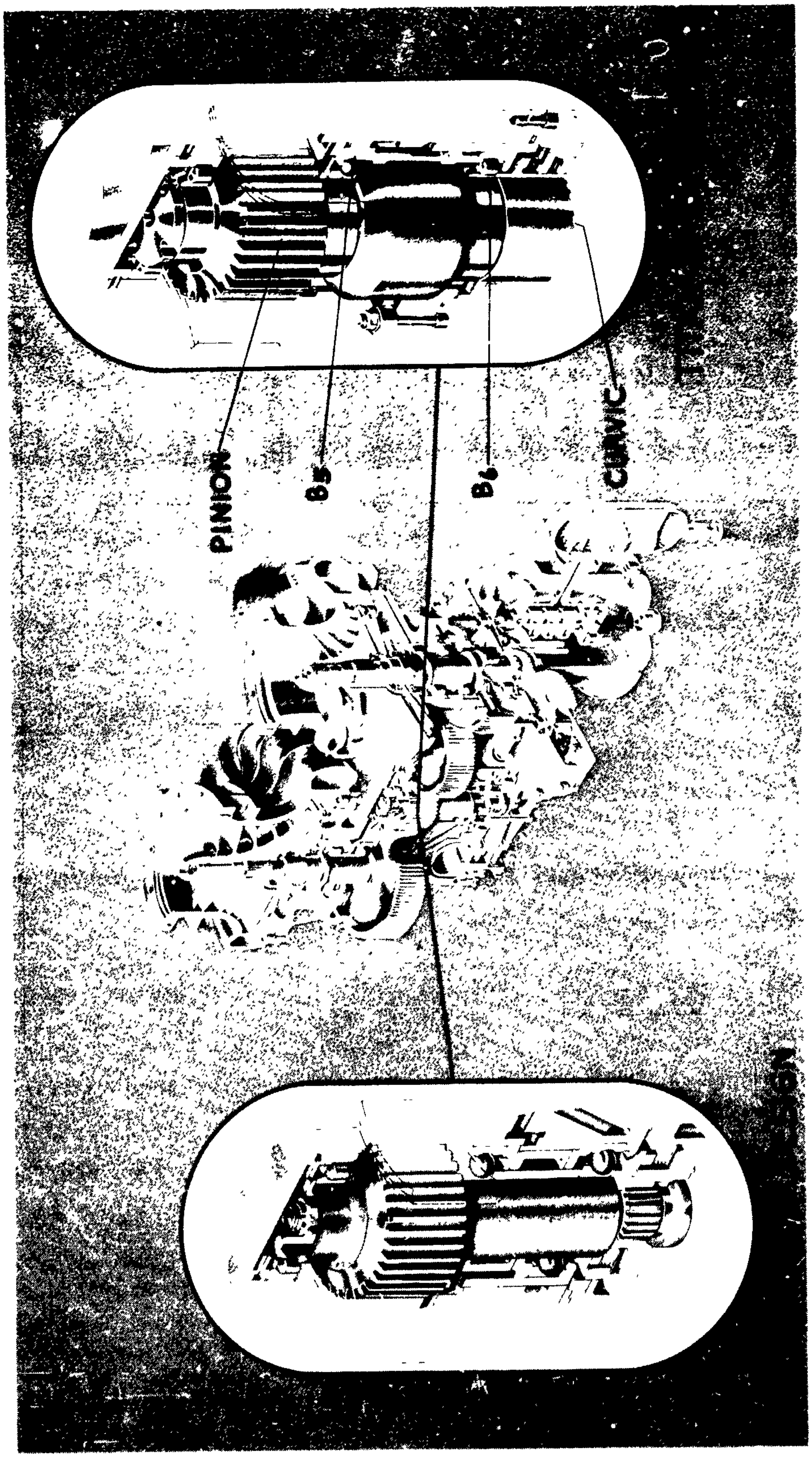


Figure 10 -- High Speed Shaft Redesign

2.1, Description of Engine (cont.)

b. The current duplex ballbearing set was replaced with a split inner race ballbearing at the center location and a cylindrical roller bearing at the lower location. The shaft assembly configuration was designed so that the ballbearing received only axial loads and roller bearing only radial loads. In addition, the lower bearing was positioned closer to the turbine rotor in order to decrease the moment.

c. Provisions were made for increasing the flow of oil to the bearings and for improved scavenging.

d. A Curvic coupling, a proprietary self-centering device, replaced the former connection between the turbine drive shaft and the gearbox high speed shaft.

e. The integral pinion gear was replaced by a splined pinion gear to allow assembly of the larger shaft.

Following a series of spin tests, the gearbox was subjected to 52 turbopump tests utilizing five different turbopump assemblies prior to engine demonstration. No failures attributable to the redesigned shaft were encountered.

Improved Capacity Lube System

The Titan III gearbox generated heat faster than it could be transferred out by the lubrication oil cooling system; therefore, the oil temperature did not reach equilibrium during the 165-sec test duration. With the increase of the Titan IIIM operating duration to 200 sec, the further increase in oil temperature that would occur was not compatible with the lubrication requirements for the gearbox.

2.1, Description of Engine (cont.)

Changes made to the lubrication system to accommodate the longer duration were:

a. Increased heat transfer capability of the oil cooler

b. Increased lube pump capacity

c. Increased oil reservoir capacity together with a change to preclude failure of the cooler attaching flange of sump shell.

d. Optimized sizing of the lube jets.

e. Correction of dimensional fits between the bearing sleeves and housings to prevent pressure loss from internal leakage.

f. Substitution of a replaceable cartridge filter with a bypass in place of the oil screen.

g. Installation of a screen at the pressurization inlet boss to the oil reservoir to prevent contamination from solid particles in the turbine exhaust.

h. Improved scavenging of the lower bearing or the high speed shaft.

i. Modification of deflector baffles in the floor plate to speed scavenging.

The lubrication system improvements were satisfactorily tested on five turbopumps before they were incorporated in the demonstration engines.

2.1, Description of Engine (cont.)

Turbine Rotors (Figure 11)

Frequent blade cracking necessitating frequent removal from inspection and high rejection rates, together with random rotor failures during hot firings, had been encountered on Program 624A. This condition was not compatible with the more rigorous reliability requirements for Titan IIIM.

A program to develop an improved rotor for the first turbine stage was authorized in August 1967. This rotor is machined from a single Waspalloy forging instead of assemblying separately cast blade segments with interlocking fir-tree attachments and securing them to the rotor hub by brazing. The 83 blades have larger fillet radii and are hollow to reduce the mass and thereby the thermal gradients and centrifugal force on the blade plot form. Rim slots at the blade root interfaces lower the natural frequency of the blade, and larger radii at the leading edge of the blade reduce thermal stresses.

Because of the late start, only limited development testing had been conducted prior to the start of engine demonstration. As a result, the fundamental weakness of the cast-blade rotor was not apparent at the time and the demonstration program was started with the production (cast-blade) rotors. Precautions were taken to submit each rotor to a single screening test followed by microscopic inspection for incipient cracks. These rotors were re-inspected after each engine test and replaced on the basis of engineering judgement. The 83-blade Waspalloy rotor was first installed prior to Test No. -205.

Profile

Closeup of Blades

Figure 11 -- Turbine Rotor

2.1, Description of Engine (cont.)

Other TPA Design Changes

The following changes were made without further development.

a. Improved OMNI and Raco seals had been incorporated on Program 624A by ECP.

b. The turbine rotor bolt locking ring and the turbine coupling retainer mechanical lock were eliminated by the redesign of the high speed shaft. The rotor bolt is now locked by a crimp-and-key type lock washer on the rotor hub.

c. Interference between the accessory drive gear and the tab on the lock washer was eliminated by a dimensional change.

d. The heat treat for the 7075 impeller nuts was changed from T-6 to T-73.

e. The studs for assembling the pump seals to the gearbox were changed from AISI 303 to A286 to eliminate galling.

f. The change in the fuel shaft deflection plate material to 6061-T6 aluminum was incorporated in the engine baseline.

g. The rotor drawings were redimensioned so as to facilitate measurements of runout after TPA buildup and therefore closer control.

h. The need for close turbine pilot tolerances to control imbalance was eliminated by the introduction of the Curvic coupling.

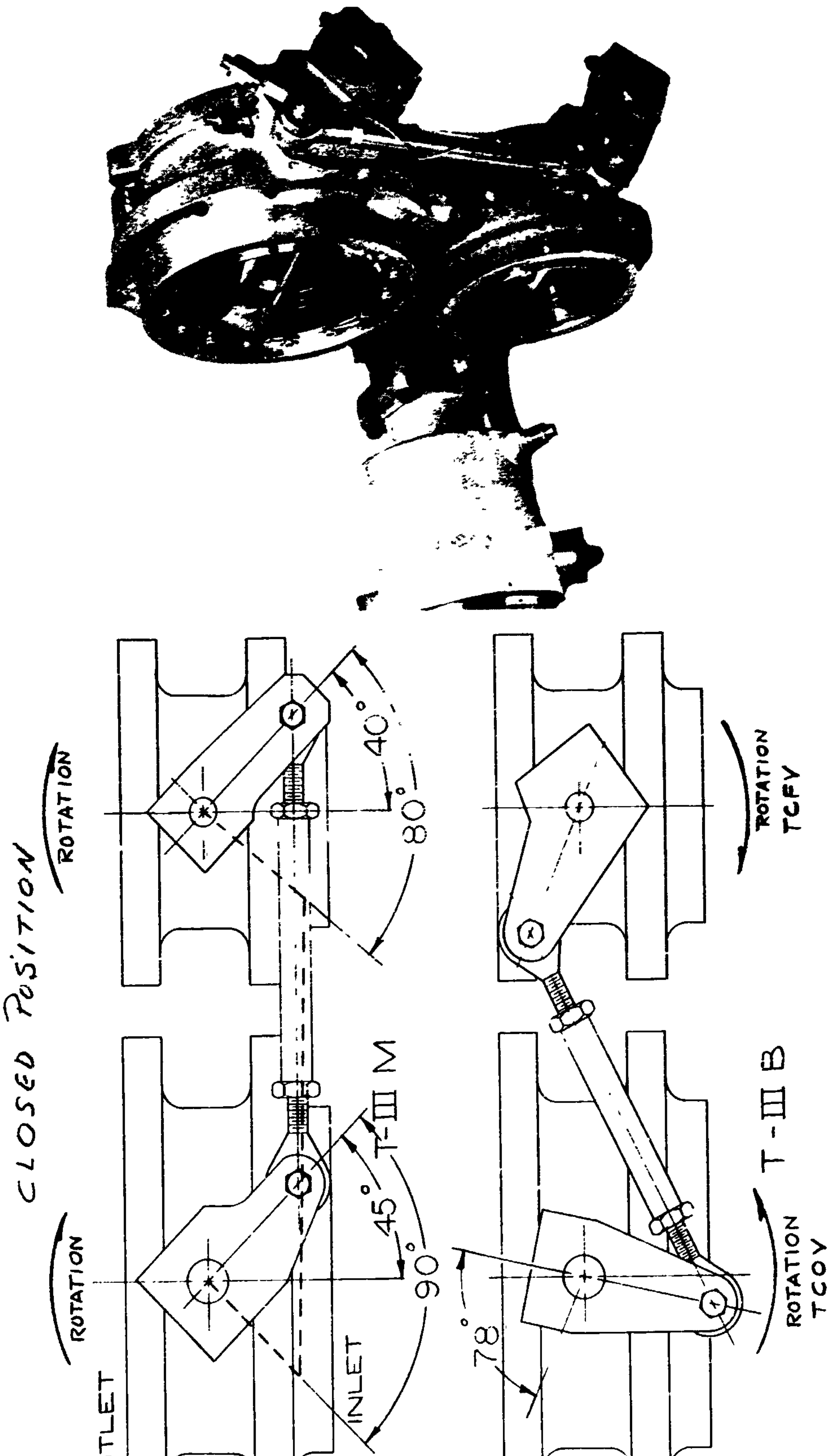


Figure 12 -- Reverse Opening Thrust Chamber Valve

2.1, Description of Engine (cont.)

i. Possible reverse installation of the turbine rotors was eliminated by making the Curvic couplings on the opposite sides of the first rotor of different size.

j. The material for the bolts attaching the first stage nozzle to the manifold was changed to Waspalloy in order to eliminate failure of the bolt shanks due to differential thermal expansion.

k. The dynamic seals and associated rotating rings developed during the AEIP program were incorporated by changes to the existing Titan III drawings.

l. The locknut on the gearbox rotating ring was redesigned to provide a positive locking tab on the washer between the nut and the shaft deflector.

2.1.3 Engine Controls

Modifications were made to the thrust chamber (propellant control) valves and to the engine (electrical) controls harness. The thrust chamber pressure switch was duplicated for redundant operation.

Thrust Chamber Valves (Figure 12)

The nylon lipseal for the fuel valve gate had a record of embrittlement from high temperature and of weakening from exposure to fuel. The oxidizer valve was subject to contamination by salt crystals which caused damage to the lipseal and shaft seals and scratched the shaft and body. The TCV actuator shaft was subject to galling and the actuator body to pitting corrosion due to moisture.

Corrections for these problems had been designed and tested during the AEIP program. These consisted of substitution of improved seal materials, lubrication, and servicing procedures. The improvements were incorporated by drawing change without further development.

2.1, Description of Engine (cont.)

Water flow tests in conjunction with the oxidizer elbow showed that reversing the direction of rotation (i.e., clockwise) of the oxidizer valve reduced the pressure drop and made the velocity profile more uniform. This change was effected by designing a new actuator link.

The redesigned thrust chamber valve assembly was installed on engine S/N RD-12 and used during the engine subassembly development testing with satisfactory results.

Redundant Thrust Chamber Pressure Switch

The thrust chamber pressure switch is a safety device that monitors chamber pressure during missile staging; if it fails to close an automatic shutdown is effected. It also initiates shutdown when chamber pressure decays below a fixed limit as with incipient propellant exhaustion. In order to improve reliability, the monitor was made redundant by installing a second switch mounted on the injector dome with separate cable leads to the interface panel. No development was necessary.

Controls Harness

The engine controls harness was modified in order to maintain the existing wiring harness design intact but with each of the ordnance and other electrical control devices supplied in duplicate at the interface but maintained electrically separate. The interface panel was redesigned to receive a new interface interconnecting box containing the additional connectors and voltage suppressors.

Electromagnetic interference control provisions were incorporated in accordance with Titan IIIM requirements. Testing to demonstrate interference control was conducted at a separate facility, but the new harness was used with the demonstration engine.

2.1, Description of Engine (cont.)

2.1.4 Flight Instrumentation

The flight instrumentation kit incorporates the Titan IIIA kit plus an additional 20 channels for instrumenting the ablative skirt and exit closure. The exit closure parameters were accommodated by slight modification of the existing interconnecting boxes. An additional interconnector was applied for each subassembly for the ablative skirt parameters. Six pressure transducers were relocated in order to clear the POGO accumulators with attendant changes in cable lengths and routings. An interface subpanel was provided for checking the exit closure parameters during installation of the closure.

The bridge balance of the resistance temperature transmitter was modified to comply with the change to the interface specification.

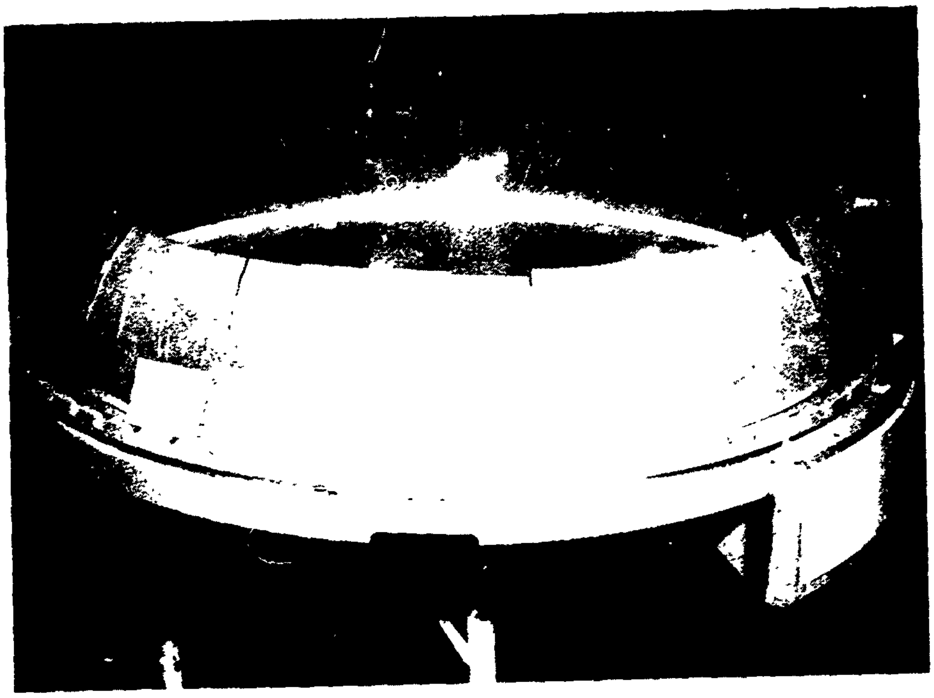
Lightweight transducers, not sensitive to vibration, were acquired for measuring gearbox (PgGB) and lube pump (Pld) pressures.

The frequency-to-dc connector was modified in order to eliminate transient voltage spikes from the output signal, which were observed during Titan IIIA flights.

2.1.5 Thrust Chamber Exit Closure (See Figure 13)

In order to protect the interior of the thrust chamber and ablative skirt against the radiation and recirculating gases and particles from the Stage 0 solid motors, an exit closure was designed to fit over the end of the ablative skirt. The closure also provides a bumper to prevent contact between the skirts during the interval that the gimbal actuators are inactive.

The closure consists of a flat disc of honeycomb structure supporting an external thermal insulator of cork. It is attached to the exit of the ablative skirt by an aluminum retaining ring. Three brackets connecting the



Panel

Ordnance Manifold

Figure 13 -- Exit Closure

2.1, Description of Engine (cont.)

Black Teflon Bootstrap Lines

Pinhole leaks attributed to electrostatic discharge had occurred occasionally in the bootstrap lines. Black teflon (Teflon impregnated with carbon) was substituted for the normally white teflon. The material change was qualified by usage on other programs.

Autogenous Hot Gas Line

The bellows assembly in the autogenous hot gas line had been subject to pitting corrosion from residue left after cleaning. The bellows was modified to make it self-draining. The line was subjected to a vibration test and a cleaning-and-storage test prior to demonstration.

Oxidizer Autogenous Line

The oxidizer autogenous line was rerouted to clear the Martin POGO actuators. The line successfully passed vibration testing prior to engine demonstration.

Gearbox Pressurization Line

The gearbox pressurization line was rerouted to conform to the modifications to the gearbox lube system. No development or testing was required prior to demonstration.

Propellant Discharge Lines

The propella·t discharge lines were modified by changing one angular dimension to compensate for the cant angle of the thrust chambers. Tripod corrosion was corrected by a change in the weld rod material. Dislocation of

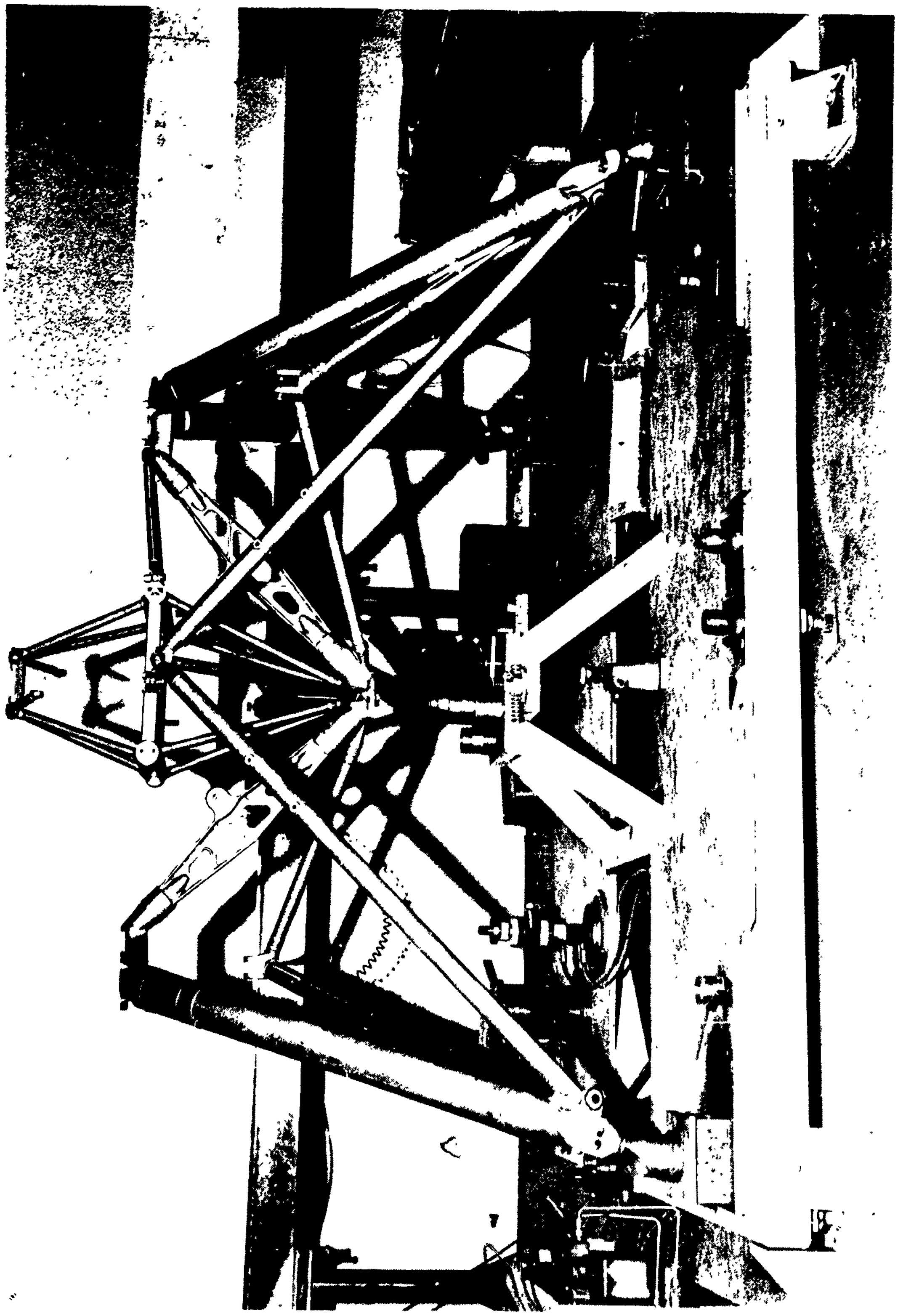


Figure 14 -- Engine Frame

2.1, Description of Engine (cont.)

the tripod inserts was corrected by providing an interference fit of the insert sockets. Female fittings were replaced by male fittings in order to decrease the number of possible leakage paths. A modification to the flanges made it possible to determine whether a seal had been omitted during assembly by providing a clear indication of leakage.

Vibration and corrosion tests were conducted on the discharge lines prior to engine demonstration.

Autogenous Lines Interface Bracket

A bracket for supporting the autogenous lines at the interface was designed to receive the weight and thrust of the Martin hoses, which heretofore had exerted stress on the engine lines. No development or demonstration was required for this change.

Hot Gas Cooler and Superheater

It had been proposed to replace the stainless steel cooling tubes in the heat exchanges with Hastelloy tubing as a measure of inhibiting pitting corrosion. Authorization was given and development was initiated; however, the authorization was later rescinded. Standard stainless steel heat exchangers, P/N 1154573-1 and P/N 216285, were used for engine demonstration.

2, Testing (cont.)

2.2 TEST OBJECTIVES AND CRITERIA

The objective of the Demonstration Test Program was to demonstrate the capability and compatibility of the improved components and to establish the adequacy of the engine system during gimballing and simulated flight conditions. The testing was conducted with prototype hardware in order to confirm that the components selected as prototype met all program objectives. Achievement of the performance and operational requirements during these tests, including sea-level start capability, qualified the engines for Titan IIIM application. Formal qualification procedures were not required.

Objectives for specific tests were divided between those to be obtained at nominal and those at peripheral conditions. The nominal performance phase was conducted to determine mixture ratio repeatability, thrust growth characteristics, autogenous system performance, thrust capability, and specific impulse. Tests at peripheral conditions were conducted to determine the engine operating capability at worst flight conditions for the combustion chamber and ablative skirts as well as engine operation at flight-minimum propellant inlet pressures.

With the demonstration engines available on the test stand it was possible also to evaluate the performance of associated Titan IIIM components not properly part of the engine and to determine their compatibility. Authorization was received from the Air Force for testing on a noninterference basis of the following items:

a. Martin-supplied refrasil covers
b. POGO fuel accumulators together with Martin pre-valves and instrumentation.

2.2, Test Objectives and Criteria (cont.)

c. Flight instrumentation components
d. Titan IIIB 12:1 ablative skirts
e. Titan IIIB (Martin-supplied) 10-sq-in. actuators
f. Thrust chamber exit closures

Secondary to the engine demonstration was the gathering of data concerning local vibrational inputs, evaluation of experimental components (new Raco seal, fuel check valve with low pressure drop, lube pump lock ring), evaluating the effects of suppressing cavitation in the fuel venturi and the leak check procedure for the turbine manifold cavity.

Criteria for meeting the performance requirements of engine demonstration are shown in Table 3 and the schedule of tests for demonstrating the engines are shown in Table 4.

Table 3 -- Demonstration Test Criteria

Parameter	Requirement
Engine Thrust, Nominal, Vacuum	520,000 lb
Minimum Sea Level Thrust	
Engine	437,000 lb
Subassembly	218,500 lb
Specific Impulse, Vacuum	
Steady State	297.0 sec
Nominal Mixture Ratio	1.91 $\pm$ 2%
Minimum Duration	200 sec

2, Testing (cont.)

2.3 TEST PLAN

All of the engine components had undergone testing during the development phase, either at the component level or in conjunction with subassembly tests utilizing engine S/N RD-12 (Figure 15), so their performance on a prototype engine system was predictable. However, not all of the prototype components had been tested together nor had they been subjected systematically to the extremes of engine operation.

The test plan shown in Table 4 allotted five tests for measuring engine performance and repeatability as defined in Table 3. These tests were to be conducted at nominal engine inlet conditions and preferably without adjustment between tests so that repeatability and thrust growth could be obtained without the use of correction factors. Five tests were assigned for monitoring engine operation at the extremes of thrust and mixture ratio that might occur during a scheduled flight. These extremes may be produced by a combination of nominal engine balance, variations in suction pressure at the turbopumps caused by decreasing tank head and increasing acceleration and variations in propellant temperature caused by tolerances in initial bulk temperature modified by aerodynamic heating.

Ablative skirts were scheduled for installation on the engine for one performance test and one peripheral test. During these tests the thrust chambers were to be gimballed for 10 second each in the pitch and yaw planes on two occasions for a total gimballing duration of 40 seconds. One peripheral test was scheduled at the minimum net positive suction head profile predicted for flight.

Table 4 -- Demonstration Test Plan

	Test	Duration	Ablative Skirt	Start	Gimbal	F/SA (Klibs)
(1)	1	20	No	N_2	No	260 ± 3%
(2)	2	200	No	Solid	No	260 ± 3%
	3	200	Yes	Solid	Yes	260 ± 3%
	4	200	No	Solid	No	260 ± 3%
	5	200	No	Solid	No	260 ± 3%
	6	200	No	Solid	No	260 ± 3%
	7	200	No	Solid	No	260 ± 3%
						Target
	8	20	No	N_2	No	260 + 3%
(3)	9	200	Yes	Solid	Yes	206 + 4%
	10	20	No	N_2	No	260 + 3%
	11	200	No	Solid	No	260 + 2%
	12	20	No	N_2	No	260 - 3%
						Target
	13	200	No	Solid	No	260 - 3%
	14	20	No	N_2	No	260 - 4%
(4)	15	200	No	Solid	No	260 - 4%

(1) Performance on calibration tests, 1, 8, 10, 12, 14, are target values only. Engine flow control devices may be changed after calibration tests to optimize desired performance.

(2) Performance on Tests 2 through 7 is corrected to standard inlet conditions. Engine flow control devices in the gas generator feed circuit and autogenous pressurization system will not be changed to maintain engine operation within specification limits on Tests 2 through 7 without SSD approval. Replacement of these flow control devices does not require an adjustment test. P_{ost} and P_{fst} must meet tolerances for a minimum of 100 sec

Table 4 (cont.)

MRE	Prop Temp, °F	P_{ost} psia	P_{fst} psia	
1.91	Nom	82 ± 10	32 ± 10	Adjustment test
1.91 ± 2%	Nom	82 ± 10	32 ± 10	Performance evaluation
1.91 ± 2%	Nom	82 ± 10	32 ± 10	MC TCA insulation installed. Performance evaluation.
1.91 ± 2%	Nom	82 ± 10	32 ± 10	Performance evaluation
1.91 ± 2%	Nom	82 ± 10	32 ± 10	Performance evaluation
1.91 ± 2%	Nom	82 ± 10	32 ± 10	Performance evaluation
1.91 ± 2%	Nom	-	-	Operate 35 oxidizer NPSH for minimum of 10 sec. Operate remaining test duration at minimum flight predicted NPSH profile.
Target 1.91 ± 2%	60 ± 5	82 ± 10	32 ± 10	Adjustment test
1.91 + 6%	35 - 40	110 ± 5	26 ± 5	Peripheral test
1.91 - 2%	60 ± 5	82 ± 10	32 ± 10	Adjustment test
1.91 - 7%	85 - 90	67 ± 5	37 ± 5	Peripheral test
1.91 + 2%	60 ± 5	82 ± 10	32 ± 10	Adjustment test
Target 191 + 6%	85 to 90	82 ± 5	32 ± 5	Peripheral test
191 - 4.3%	35 to 40	82 ± 10	32 ± 10	Adjustment test
191 - 4.3%	35 to 40	82 ± 5	32 ± 5	Peripheral test

(3) Performance on Tests 9, 11, and 13 and 15 is uncorrected summarized from FS_1 to FS_2. Test is acceptable providing P_{ost} and P_{fst} meet tolerances for a minimum of 100 sec.

(4) Any tests required in excess of the 15 tests planned on each of two engines (total 30 tests) and any hardware replacement (other than soft goods and time/cycle sensitive components) shall be subject to separate contractual authorization in accordance with the clause of the contract entitled "changes."

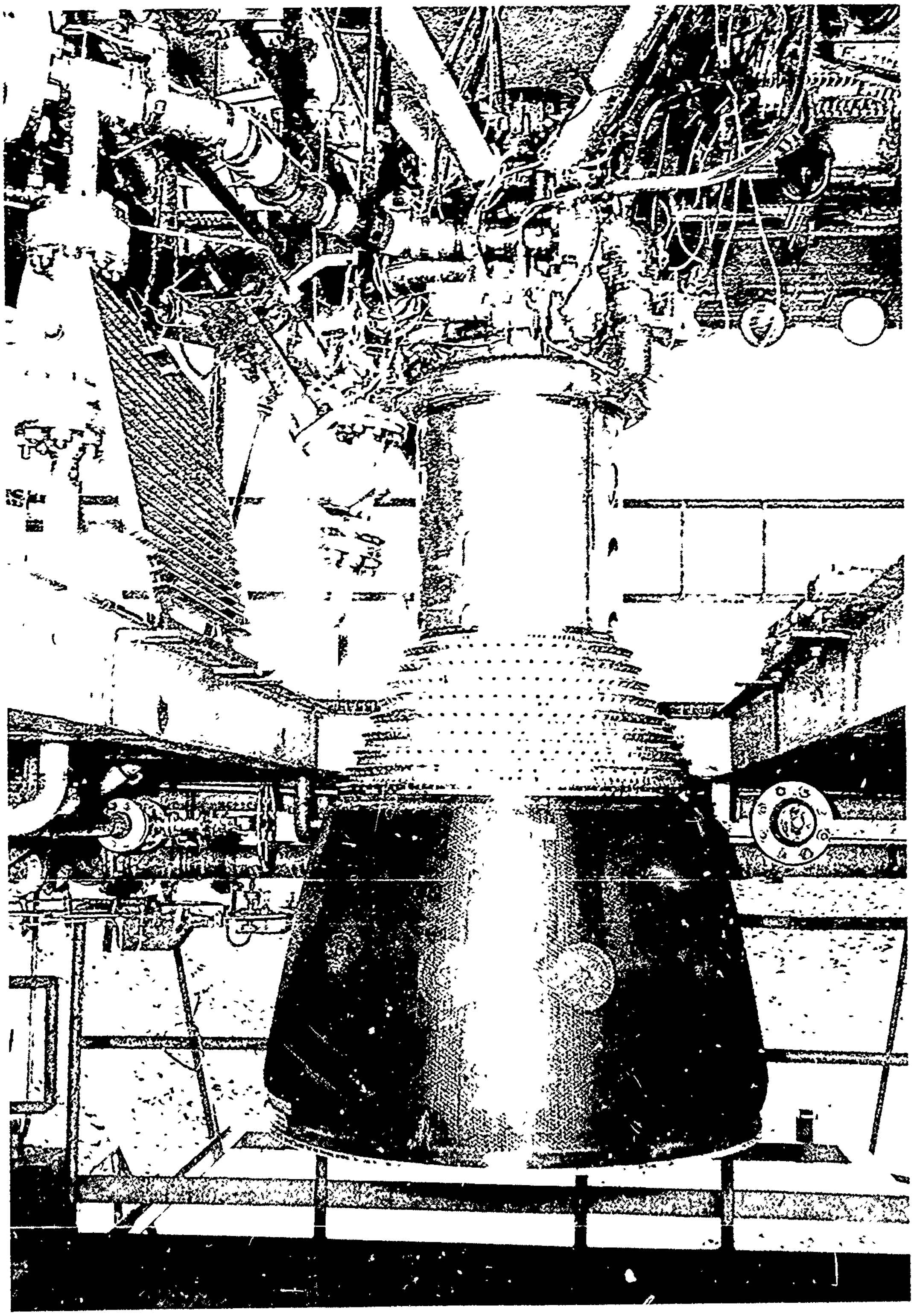


Figure 15 -- Engine Subassembly S/N RD-12

2.3, Test Plan (cont.)

The foregoing tests were all scheduled for 200 seconds duration. Five additional tests were scheduled for 20 seconds duration each to make necessary adjustments in the engine balancing orifices and venturis to ensure that the desired steady-state operating point would be achieved.

Authorizations for testing of additional components and for modifying the test conditions were received by Change Orders. These modifications are discussed in Section 2.5 under the discussion of the specific tests to which they were applicable.

See Foldout on Back Cover

Figure 16 -- Instrumentation Locations

2, Testing (cont.)

2.4 TEST SETUP AND OPERATION

Testing was performed in accordance with Engine Test Operating Procedure 9111-87. This procedure is reproduced in full as Appendix B. Figure 16 is a flow diagram of the engine and test stand, showing also the relevant instrumentation locations.

All testing was conducted in Test Zone G, stand firing positions G-1 and G-2. Prior to starting demonstration testing two tests were conducted with engine S/N RD-12 to checkout position G-2 after the installation of special test equipment for the demonstration series. The first test, of 20 seconds duration, verified the satisfactory operation of the new equipment. The second test, also satisfactory, was for 200 seconds duration and included gimballing.

Upon receipt of the engine at the Test Area a visual inspection was made by the Test Engineer and the Quality Control Inspector to ensure that the engine was in acceptable condition. Close up photographs were then taken for documentation.

Following completion of the inspection the engine was installed on the test stand and the necessary propellant, instrumentation, and drain and purge lines were connected in accordance with specifications. Additional photographs were taken of the engine in place.

Before each test a Declaration of Intent was submitted by Engineering defining the test objectives, firing duration, operating and kill parameters, and the hardware and parameters to be monitored for the reliability record. The orifices and venturis to be used and the tank pressure setting were also specified.

2.4, Test Setup and Operation (cont.)

Advanced notification was given to Air Force and Aerospace Corporation representatives so that they could witness the tests.

Prior to each test the applicable operations shown in Table 5 were performed to prepare the engine for firing. These included physical measurements, functioning of valves and other controls and checks for leakage.

A visual survey was made of the engine as soon after firing as practicable in order to record any hardware damage such as hot spots, leakage or other irregularities. Each such instance was immediately documented by photographs. The postfire procedures listed in Table 5 were then performed. These included measurement of critical dimensions, disassembly and inspection of components where test conditions indicated damage may have been incurred, cleaning and purging, functioning of controls, leakage tests, and repair and replacement of damaged or time/cycle critical components.

Repair or replacement of all items not part of routine maintenance was always preceded by written authorization from the Air Force. The operations were performed in the presence of Quality Control representatives and the action are documented in the time/cycle log, Section 7, Table 44, of this report.

Table 5 -- Engine Prefire/Postfire Check Requirements

	Function	Refer. Para.*	Prefire			Postfire	
			Initial Test	Repl./Remov	Normal	Conditional	Normal
A.	Inspections						
	Engine	3.5.1.1			X		X
	CC & Skirt Diameters	3.5.1.2	X	X			X
	CC-Inj. Gap	3.5.1.3	X		X		X
	Tripod-Disch. Lines	3.5.1.4	X	X		X	
	Turbine-TPA	3.5.1.5				X	
	Impeller/Hsg.-TPA	3.5.1.6				X	
	Gimbal Insp.	3.5.1.7					X(1)
B.	Functional/Checkouts						
	Engine	3.5.2.1	X	X			
	Gimbal	3.5.2.2			X(1)		
	N_2 Start Calib.	3.5.2.3	X	X			
	TPA Torque	3.5.2.4	x				X
	Purge Calib.	3.5.2.5	X	X			
C.	Leak Checks						
	Propellant Systems	3.5.3.1	X	X			X
	P_{c5}	3.5.3.2	X	X			X
	Hot Gas (TPA/GGA)	3.5.3.3	X	X			X
	Autogenous	3.5.3.4	X	X			X
	Electrical Controls	3.5.3.5	X	X			X
	CC	3.5.3.6	X	X			X
	Propellant Supply	3.5.3.7	X	X			X
	Seals-TPA	3.5.3.8	X	X			X
D.	Servicing/Installation						
	Venturi/Orifices	3.5.4.1		X			
	Solid Cartridge	3.5.4.2			X		X
	Burst Discs	3.5.4.3			X		
	Ablative Skirt	3.5.4.4			X(2)		X(2)
	Raco Seals-CC	3.5.4.5					X
	Systems Drain	3.5.4.6			X		X
	Autogenous Cleaning	3.5.4.7					X
	Engine Cleaning	3.5.4.8					X
	Lube Oil/Filter	3.5.4.9	X		X		X
E	Other						
	Photography	3.5.5.1			X	X	

(1) Gimbal tests only.
(2) Ablative skirt tests only.
* Engine Test Operating Procedure. Vide Appendix B.

2, Testing (cont.)

2.5 NARRATIVE OF TESTING

The LR87-AJ-11 Engine Demonstration Test Program consisted of a total of 31 tests on two LR87-AJ-11 engine assemblies.

Fifteen tests were conducted with engine S/N 14 from 20 December 1967 through 27 August 1968. The accumulated test duration was 1844.97 seconds. The 15 tests consisted of six adjustment tests, four performance evaluation tests, one net positive suction head test and four peripheral evaluation tests. One test failed to achieve the scheduled duration of 200 seconds.

Sixteen tests were conducted with engine S/N 15 from 3 June through 17 October 1968. The accumulated test duration was 2114.74 seconds. The 16 tests consisted of five adjustment tests, six performance evaluation tests (including one malfunction), one net positive suction head evaluation test and four peripheral evaluation tests.

Tabular descriptions of the tests are presented in Tables 6 and 8 for engine S/N 14 and 3 and 4 for engine S/N 15. The tests are presented by test series numbers in the order in which they were performed rather than by the test number designations identified in the Implementation Test Plan.

The following discussions present a brief commentary on the significant features of each test. Specific details of data and component evaluations or discrepancies are presented in the subsequent major sections.

Table 6 -- Test Summary -- Engine S/N 1

AGC Test Number	Test Plan No.	Date	Test Stand	Duration `ched	Act.	Start Mode	Ablat. Skirt SN	Gimbal	F K lb.	MRE
-201	1	12-20-67	G-2	[illegible]	19.657	N2	No	No	260	1.91
-202	2	12-29-67	G-2	200	200.825	Solid	No	No	260±3%	1.91±2
-203	4	1-10-68	G-2	200	200.585	Solid	No	No	260±3%	1.91±2
-204	3	3-11-68	G-2	200	115.438	Solid	25&37	Yes	260±3%	1.91±2
-205	5	4-4-68	G-2	20	20.851	N2	No	No	260±3%	1.91±2
-206	6	4-10-68	G-2	200	200.925	Solid	25&37	Yes	260±3%	1.91±2
-207	7	4-29-68	G-2	200	200.599	Solid	No	No	260±3%	1.91±2
-208	8	5-4-68	C-2	20	21.215	N2	No	No	260±3%	1.91±2
-209	14	7-1-68	G-1	20	20.575	N2	No	No	260-4%	1.91-4
-210	15	7-5-68	G-1	200	200.315	Solid	No	No	260-4%	1.91-4
-211	10	7-10-68	G-1	20	20.744	N2	No	No	260+3%	1.91-2
-212	11	7-12-68	G-1	200	201.006	Solid	No	No	260+2%	1.91-7
-213	12	7-16-68	G-1	20	20.762	N2	No	No	260-3%	1.91+2
-214	13	7-22-68	G-1	200	201.013	Solid	003 & 005	No	260-3%	1.91+6
-215	9	8-27-68	G-2	200	200.458	Solid	32&33	Yes	260+4%	1.91+6

mmary -- Engine S/N 14

F K lb.	MRE	Prop. Temp. °F	Post psia	Pfsc psia	Objectives/Remarks
260	1.91	60±5	82±10	32±10	Adjustment Test. Gas Cooler Accelerometers. Satisfactory Test.
260±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation Test. Hot Gas Cooler Accelerometers. Satisfactory Test.
260±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation Test. Hot Gas Cooler Accelerometers. Satisfactory Test. SA 2 CC replaced post test.
260±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation, Refrasil Insulation Gas Cooler Accelerometers. Premature Shut-down caused by SA 2 turbine rotor failure. Replaced SA 2 TPA.
260±3%	1.91±2%	60±5	82±10	32±10	Adjustment Test. First Test 83-blade rotors. Interface Panel Accelerometers. Satisfactory Test.
260±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation Test. Refrasil Insulation. Interface Panel Accelerometers. Satisfactory Test.
260±3%	1.91±2%	60±5	---	---	NPSH Evaluation Test. Oxidizer (44') and Fuel (43') at minimum. Oxidizer at 35'. Interface Panel Accelerometers. Satisfactory Test.
260±3%	1.91±2%	60±5	82±10	32±10	Adjustment Test. Satisfactory Test.
260-4%	1.91-4.3%	35-40	82±10	32±10	Adjustment Test. Satisfactory Tes
260-4%	1.91-4.3%	35-40	82±10	32±10	Peripheral Evaluation Test. POGO Fuel Accumulators. Flight Instrumentation (TOS, TFS, TfPOI, DC Conv., Pc5). Satisfactory Test.
260+3%	1.91-2%	60±5	82±10	32±10	Adjustment Test. Flight Instrumentation (TOS, TFS, ToPOI, TfPOI, DC Conv.). Satisfactory Test.
260+2%	1.91-7%	85-90	67±5	37±5	Peripheral Evaluation Test. POGO Fuel Accumulators. Flight Instrumentation (TOS, DC Converter, Pc5). Satisfactory Test.
260-3%	1.91+2%	60±5	82±10	32±5	Adjustment Test. Flight Instrumentation (TOS). Satisfactory Test.
260-3%	1.91+6%	85-90	110±5	26±5	Peripheral Evaluation Test. Flight Instrumentation (TFS, ToPOI, TfPOI), 12:1 Ablative Skirts, MMB 10 in.-sq. Gimbal Actuators. Modified Refrasil Insulation. Satisfactory Test.
260+4%	1.91+6%	35-40	110±5	26±5	Peripheral Evaluation Test, Flight Instrumentation (TFS, ToPOI), POGO Fuel Accumulators, SA 2 Fuel Cavitation Suppression, Refrasil Insulation. Low ΔP Fuel GGCKV. Satisfactory Test.

2

Table 7 -- Test Summary -- Engine S/N

AGC Test Number	Test Plan No.	Date	Test Stand	Duration Sched	Duration Act.	Start Mode	Ablat. Skirt SN	Gimbal	F K lb.	MRE
-301	1	6-3-68	G-2	20	20.669	N2	No	No	260	1.91
-302	2	6-6-68	G-2	200	201.008	Solid	No	No	260±3%	1.91±2%
-303	4	6-14-68	G-2	200	200.341	Solid	No	No	260±3%	1.91±2%
-304	5	6-18-68	G-2	200	200.843	Solid	No	No	260±3%	1.91±2%
-305	3	6-24-68	G-2	200	200.645	Solid	35&38	Yes	260±3%	1.91±2%
-306	6	7-26-68	G-2	200	200.746	Solid	No	No	260±3%	1.91±2%
-307	7	8-1-68	G-2	200	200.470	Solid	14&21	Yes	260±3%	1.91±2%
-308	10	8-14-68	G-2	20	20.977	N2	No	No	260±3%	1.91-2%
-309	11	8-15-68	G-2	200	2.569	Solid	No	No	260±2%	1.91-7%
-310	11	8-16-68	G-2	200	200.361	Solid	No	No	260+2%	1.91-7%
-311	12	9-17-68	G-2	20	21.340	N2	No	No	260-3%	1.91-2%
-312	13	9-19-68	G-2	200	201.114	Solid	No	No	260-3%	1.91+6%
-313	14	9-28-68	G-2	20	20.845	N2	No	No	260-4%	1.91-4.3%
-314	15	10-1-68	G-2	200	200.908	Solid	No	No	260-4%	1.91-4.3%
-315	8	10-3-68	G-2	20	21.095	N2	No	No	260+3%	1.91+2%
-316	9	10-17-68	G-2	200	200.809	Solid	39&40	Yes	260+4%	1.91+6%

mary -- Engine S/N 15

F lb.	MRE	Prop. Temp. °F	Post psia	Pfst psia	Objectives/Remarks
0	1.91	60±5	82±10	32±10	Adjustment Test. Satisfactory Test.
0±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation. Satisfactory Test.
0±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation. Satisfactory Test.
0±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation. Satisfactory Test.
0±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation, Refrasil Insulation. Satisfactory Test.
0±3%	1.91±2%	60±5	82±10	32±10	Performance Evaluation. Satisfactory Test.
0±3%	1.91±2%	60±5	---	---	NPSH Evaluation - Oxidizer (44') and Fuel (43') at minimum. Oxidizer at 35' Piggyback-closure covers SN 006 and 005. Refrasil Insulation. Satisfactory Test.
0±3%	1.91-2%	60±5	82±10	32±10	Adjustment Test, Experimental RACL Seals. Flight Instrumentation (Pld & PgGB). Martin Fuel Prevalves. Satisfactory Test.
0±2%	1.91-7%	85-90	67±5	37±5	Peripheral Test - Experimental RACO Seals, Flight Instrumentation (Ped and PgGB), Martin Fuel Prevalves, POGO Fuel Accumulators SN 101 and 130. Invalid Test, SA 1 PSVOR Failure.
0+2%	1.91-7%	85-90	67±5	37±5	Repeat of Test -309. Satisfactory Test.
0-3%	1.91+2%	60±5	82±10	32±10	Adjustment Test - Flight Instrumentation (Pld and PgGB) Martin Fuel Prevalves. Satisfactory Test.
0-3%	1.91+6%	85-90	110±5	26±5	Peripheral Test - Flight Instrumentation (Pld andPgGB), Martin Fuel Prevalves, POGO Fuel Accumulators. Satisfactory Test.
0-4%	1.91-4.3%	35-40	82±10	32±10	Adjustment Test - Martin Fuel Prevalves. Special POGO Instrumentation. Satisfactory Test.
0-4%	1.91-4.3%	35-40	82±5	32±5	Peripheral Test - Martin Fuel Prevalves and POGO Fuel Accumulators, Special POGO Instrumentation. Satisfactory Test.
0+3%	1.91+2%	60±5	82±10		Adjustment Test - Martin Fuel Prevalves (Pld and PgGB). Satisfactory Test.
0+4%	1.91+6%	35-40	110±5	26±5	Peripheral Test - Martin Fuel Prevalves, and POGO Fuel Accumulators, Refrasil Insulation, Flight Instrumentation (Pld and PgGB), Exit Closure Covers. Satisfactory Test.

2

Table 8 -- Engine Adjustments, Orifice and Venturi Sizes
Engine S/N 14

Test No.	ODO in.	Subassembly 1 FDO in.	Subassembly 1 OBTV Kv	FBTV Kv	ODO in.	Subassembly 2 FDO in.	Subassembly 2 OBTV Kv	FBTV Kv	FPN in.	Autogenous FPBO in.	Autogenous OPBO in.	OPBPO* in.	OPV Kv
201	--	3.127	0.0253	0.3600	--	--	0.0268	0.3917	0.510	0.430	0.595	0.320	0.0824
202	--	3.127	0.0253	0.3550	--	--	0.0268	0.3917	0.470	0.410	0.595	0.320	0.0824
203	--	3.127	0.0253	0.3550	--	--	0.0268	0.3917	0.440	0.410	0.595	0.320	0.0837
204	--	3.127	0.0253	0.3550	--	--	0.0268	0.3917	0.440	0.410	0.595	0.320	0.0837
205	--	3.127	0.0261	0.3830	--	--	0.0282	0.4080	0.440	0.410	0.595	0.320	0.0837
206	3.970	--	0.0268	0.3830	3.900	--	0.0282	0.4080	0.440	0.410	0.595	0.320	0.0837
207	3.970	--	0.0268	0.3830	3.900	--	0.0282	0.4080	0.440	0.410	0.595	0.320	0.0837
208	--	3.300	0.0274	0.3970	--	3.400	0.0298	0.4320	0.440	0.410	0.595	0.320	0.0837
209	3.400	--	0.0261	0.3740	3.250	--	0.0278	0.4080	0.440	0.410	0.595	0.320	0.0837
210	3.400	--	0.0261	0.3740	3.250	--	0.0278	0.4080	0.440	0.410	0.595	0.320	0.0837
211	3.70	--	0.0278	0.0460	3.40	--	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0837
212	3.70	--	0.0278	0.4060	3.550	--	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0837
213	--	3.280	0.0253	0.3630	3.700	--	0.0268	0.3830	0.440	0.410	0.595	0.320	0.0837
214	--	3.000	0.0253	0.3630	--	--	0.0268	0.3917	0.440	0.410	0.595	0.320	0.0837
215**	--	3.050	0.0278	0.4060	--	--	0.0300	0.435	0.440	0.410	0.595	Blank	0.1034

*1 in each Superheater
**GGFCKVo = 0.618 in. orifice SA 2

Table 9 -- Engine Adjustments, Orifices and Venturi Sizes
Engine S/N 15

	Subassembly 1				Subassembly 2				Autogenous				
Test No.	ODO, in.	FDO, in.	OBTV, K_v	FBTV, K_v	ODO, in.	FDO, in.	OBTV, K_v	FBTV, K_v	FPN, in.	FPBO, in.	OPBO, in.	OPBPO,* in.	OPV, K_v
301	---	3.280	0.0267	0.3815	3.870	---	0.0285	0.4060	0.440	0.410	0.595	0.320	0.0833
302	---	---	0.0 267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0833
303	---	---	0.0267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0833
304	---	---	0.0267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0833
305	---	---	0.0267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	0.320	0.0833
306	---	---	0.0267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	Blank	0.0848
307	---	---	0.0267	0.3815	3.620	---	0.0299	0.4260	0.440	0.410	0.595	Blank	0.0848
308	3.700	---	0.0272	0.3900	3.550	---	0.0299	0.4280	0.440	0.410	0.595	Blank	0.1072
309	3.700	---	0.0272	0.3900	3.550	---	0.0299	0.4280	0.440	0.410	0.595	Blank	0.1072
310	3.700	---	0.0272	0.3900	3.550	---	0.0299	0.4280	0.440	0.410	0.595	Blank	0.1072
310	---	3.100	0.0253	0.3550	---	3.400	0.0272	0.3830	0.440	0.410	0.595	Blank	0.1034
312	---	3.100	0.0253	0.3550	---	3.400	0.0272	0.3830	0.440	0.410	0.595	Blank	0.1034
313	3.40	---	0.0253	0.3590	3.300	---	0.0279	0.3970	0.440	0.410	0.595	Blank	0.1113
314	3.40	---	0.0253	0.3590	3.300	---	0.0279	0.3970	0.440	0.410	0.595	Blank	0.0848
315	---	3.100	0.0268	0.3830	---	3.400	0.0291	0.4320	0.440	0.410	0.595	Blank	0.1034
316	---	3.100	0.0268	0.3970	---	3.400	0.0291	0.4320	0.440	0.410	0.595	Blank	0.1034

* 1 in each superheater

2.5, Narrative of Testing (cont.)

2.5.1 Engine S/N 14, Test Series 3051-D07-1A

Test No. -201

Figures 17, 18, and 19 show views of the engine as initially installed at Test Stand G-2.

The initial test on Engine S/N 14 was a satisfactory adjustment test for 19.657 seconds duration. The test was terminated early following a loss of water pressure for the deflector plate (test facility).

With exception of the performance of the fuel autogenous pressurization system, all primary and secondary performance parameters were within specification limits (CEI 005002A, Tables I-A and I-B).

The postfire inspections disclosed that combustion chamber S/N 020 on Subassembly 2 had incurred slight erosion to the forward flange above tube No. 64. In addition, one strand of wire wrap was loose, accompanied by flaking epoxy. Both conditions were accepted for retest of the engine.

Following normal servicing procedures, balance changes, and replacement of the injector-to-chamber Raco seals and both turbine kit rotors, the engine was readied for the first performance test.

Test No. -202

This was a satisfactory performance evaluation test for 200.825 second duration. The hot-gas cooler was instrumented with three accelerometers.

All primary and secondary performance parameters were within specification limits. The erosion, wire looseness, and epon flaking noted after the previous test did not increase measurably.

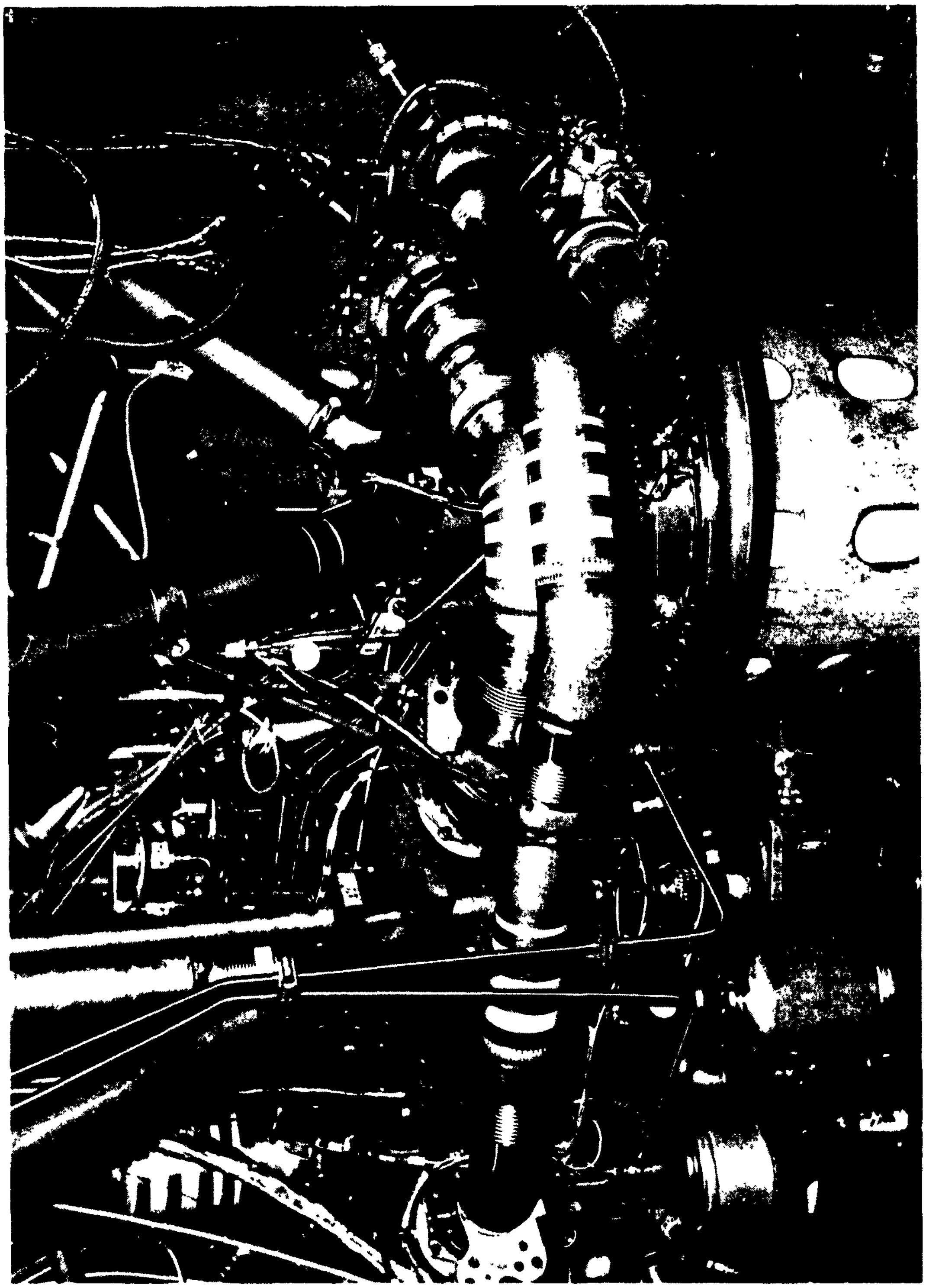


Figure 17 -- Engine S/N 14 -- Discharge Lines

2.5, Narrative of Testing (cont.)

Following replacement of injector-to-chamber Raco seals, normal servicing procedures, and replacement of turbine rotors on Subassembly 2, the engine was accepted for retest.

Test No. -203

This was the second satisfactory performance evaluation test for 200.585 seconds duration. The primary engine performance parameters were within specification limits. With exception of an excessive thrust decay rate during shutdown, all secondary parameters were also within the specification limits.

During turbine assembly inspections, two anomalies were noted in TPA S/N 010 on Subassembly 2: excessive lube oil was found in the turbine assembly and there was no torque on the rotor bolt. The TPA was returned to manufacturing for inspection, after which it was reinstalled on the engine.

Combustion chamber S/N 020 sustained new damage. Single cracks were noted above tubes No. 44 and No. 108 on the forward closure band and tube No. 64 had a crown crack. No further looseness in the wire wrap from the previous tests was observed. The combustion chamber was removed for repair, but was subsequently rejected and replaced with chamber S/N 017.

Following the normal servicing procedures, and replacement of the turbine rotors on Subassembly 1 and injector-to-chamber Raco seals, the engine was acceptable for retest.

Test No. -204

This was the third performance evaluation test, scheduled for 200 seconds duration. It was conducted with 15:1 ablative skirts installed on the thrust chambers with overlying Refrasil insulation panels similar to

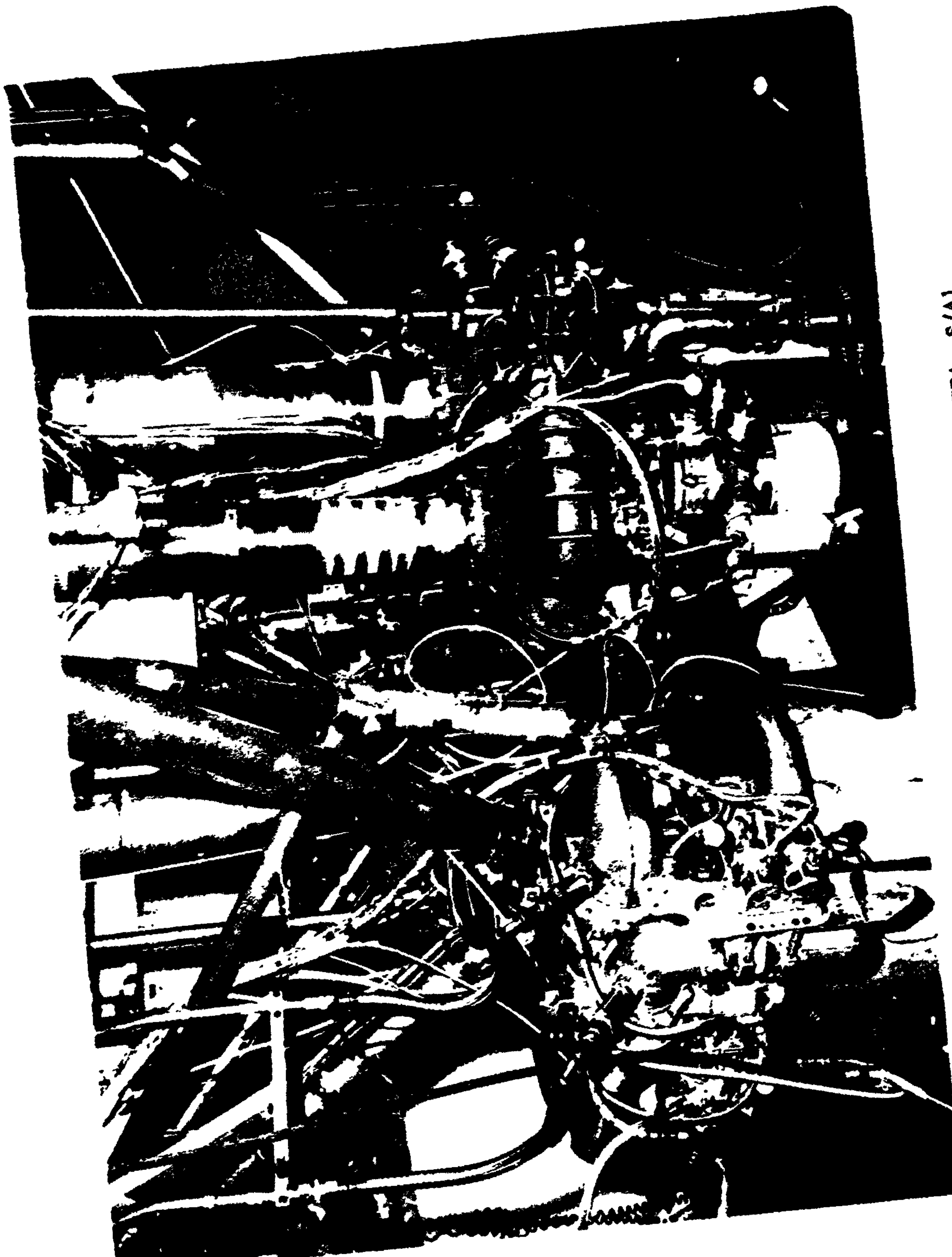


Figure 18 -- Engine S/N 14 -- TCA, S/A2; TPA, S/A1

2.5, Narrative of Testing (cont.)

those shown in Figure 5. Gimballing was performed in both the pitch and the yaw planes. The firing was terminated after 115.4 seconds because of the failure of the first rotor in TPA S/N 010 on Subassembly 2, but only after the primary test objectives had been achieved.

The rotor was of the fir-tree design and it had been installed in the turbopump as an interim measure to permit testing until the new single-forging rotor became available. As it was not a prototype part, no test penalty was assessed. TPA S/N 010 was replaced with TPA S/N 006.

During the start transient, all parameters dipped momentarily and then returned to their normal levels. The dip is attributed to a gas bubble in the fuel feed system.

The postfire leak checks disclosed internal leakage of the hot-gas cooler S/N 753. The unit was replaced with S/N 755.

The injectors S/N 697 and S/N 696, on Subassemblies 1 and 2 respectively, incurred cracks in the baffle base weld that exceeded specification limits. Both injectors were removed for repair.

Combustion chamber S/N 017 on Subassembly 2 exhibited one small spot of erosion on the forward flange. The chamber was accepted for retest without repair.

Both rotors in TPA S/N 008 (Subassembly 1) were replaced. The replacement first rotor was an experimental 83-blade Waspalloy rotor.

Following the component changes, rebalance, inspections, replacing injector-to-chamber Raco seals, and servicing, the engine was accepted for retest.

Figure 19 -- Engine S/N 14 -- Hot Gas Cooler Installation

2.5, Narrative of Testing (cont.)

Test No. -205

This was a satisfactory adjustment test for 20.8 seconds duration. The engine performance was within prescribed specification limits. The electrical interface panel and junction box were instrumented to provide data for vibrational evaluations.

Combustion chamber S/N 017 (Subassembly 2) incurred one new spot of erosion on the forward flange. The unit was accepted for retest without repair.

Following normal servicing procedures, balance changes and injector-to-chamber Raco seal replacement, the engine was accepted for retest.

Test No. -206

This was a satisfactory performance evaluation test for 200.925 seconds duration. Ablative skirts were mounted on the thrust chambers and Refrasil insulation panels were installed. Gimballing was demonstrated. The electrical interface panel and junction box were instrumented to provide data for vibrational evaluations.

All primary and secondary performance parameters were within prescribed specification limits.

Four cracks were noted in baffle base welds of each injector. The injectors were removed, repaired and accepted for retest.

Following normal servicing procedures, and replacement of injector-to-chamber Raco seals, the engine was accepted for retest.

2.5, Narrative of Testing (cont.)

Test No. -207

This was a satisfactory net positive suction head (NPSH) test for 200.5 seconds duration. The electrical interface panel and junction box were instrumented to provide data for vibrational evaluation. Prior to test, the combustion chambers were interchanged between subassemblies in order to acquire specific performance evaluations for the injectors.

The NPSH objective was attained by manipulation of the propellant tank pressures early in the test to provide a minimum oxidizer NPSH of 44 ft concurrently with a minimum fuel NPSH of 43 ft; then, while lowering the oxidizer NPSH to approximately 35 ft, the fuel suction pressure was increased to a nominal run condition.

Injectors S/N 697 and S/N 696 on Subassemblies 1 and 2 respectively each had three baffle weld cracks. Both injectors were accepted for retest without repair.

Combustion chamber S/N 019 on Subassembly 2 had two areas of minor leakage. At the tube-to-flange joint, "wetness" was noted across 29 tubes. The other leak was located above the throat on one tube. The chamber was accepted for retest without repair.

Following normal servicing procedures, balance changes and replacement of the injector-to-chamber Raco seals, the engine was accepted for retest.

Test No. -208

This was a satisfactory adjustment test for 21.215 seconds duration.

2.5, Narrative of Testing (cont.)

Following the test, the engine assembly was returned to the Manufacturing area to repair the baffle welds, repair of leakage in the combustion chamber and inspections of the turbine kits and gearboxes prior to the next test. Combustion chamber S/N 019 was subsequently replaced with Chamber S/N 092 on Subassembly 2.

Test No. -209

This was a satisfactory adjustment test for 20.575 seconds duration. There was no damage observed to the engine.

Following normal servicing procedures and replacement of the injector-to-chamber Raco seals the engine was accepted for retest.

Test No. -210

This was a satisfactory peripheral evaluation test for 200.3 seconds duration. Martin POGO Fuel Accumulators and five Flight Instrumentation transmitters were installed prior to test. Engine performance was within the desired test target values. No hardware damage was observed subsequent to the test.

Following normal servicing procedures and replacement of injector-to-chamber Raco seals the engine was accepted for retest.

Test No. -211

This was a satisfactory adjustment test for 20.7 seconds duration. The engine was equipped with seven flight instrumentation transmitters. No hardware damage was observed subsequent to the test.

2.5, Narrative of Testing (cont.)

Following normal servicing procedures, balance changes, and replacement of injector-to-chamber Raco seals, the engine was accepted for retest.

Test No. -212

This was a satisfactory peripheral evaluation test for 201.0 seconds duration. Martin POGO fuel accumulators were installed prior to the test. The engine was equipped with three flight instrumentation transmitters.

Two cracks were noted in the baffle base welds of each injector. Injector S/N 696 on Subassembly 2 had a slot (3 holes in length) on one baffle tip. The injector were accepted for retest without repair.

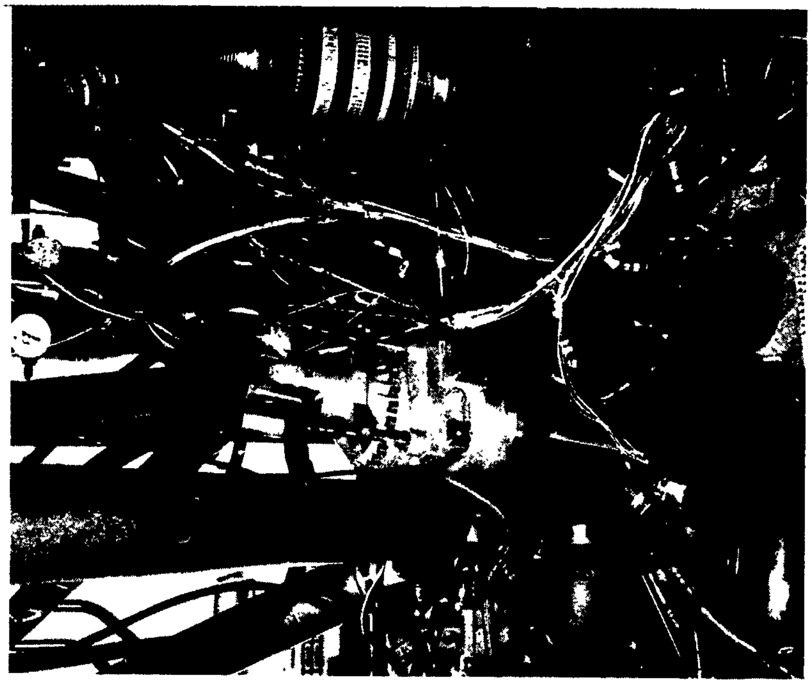
Leakage too slight to measure was detected in a crown crack in tube No. 64 of combustion chamber S/N 017. A similar occurrence had been noted on chamber S/N 017 following Test No. -203 with the same injector. The combustion chamber was accepted for retest without repair.

Turbine seal leakage on TPA S/N 008 (Subassembly 1) exceeded the allowable maximum; however, the unit was accepted for retest without replacing the seal.

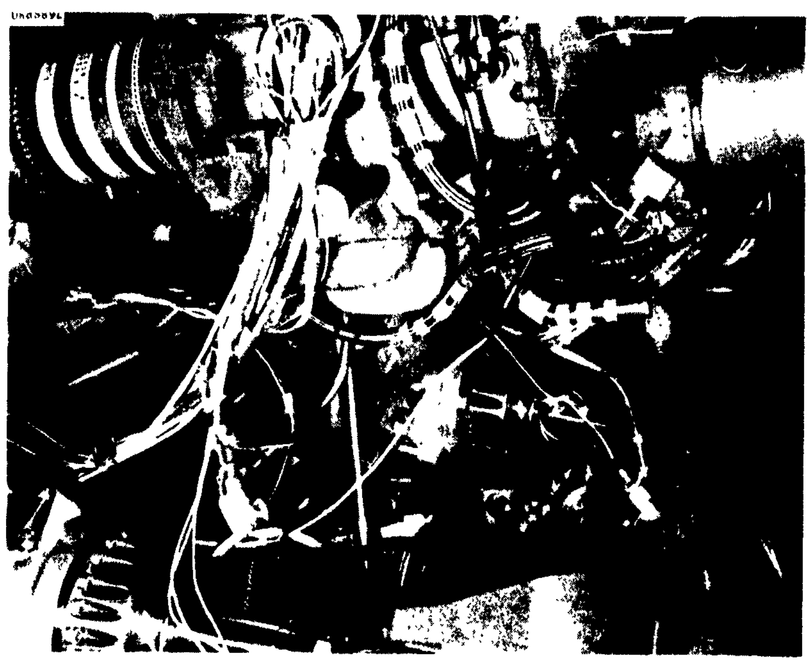
Following normal service procedures, balance changes and injector-to-chamber Raco seal replacements, the engine was accepted for retest.

Test No. -213

This was a satisfactory adjustment test for 20.7 seconds duration. The engine was equipped with three flight instrumentation transmitters.

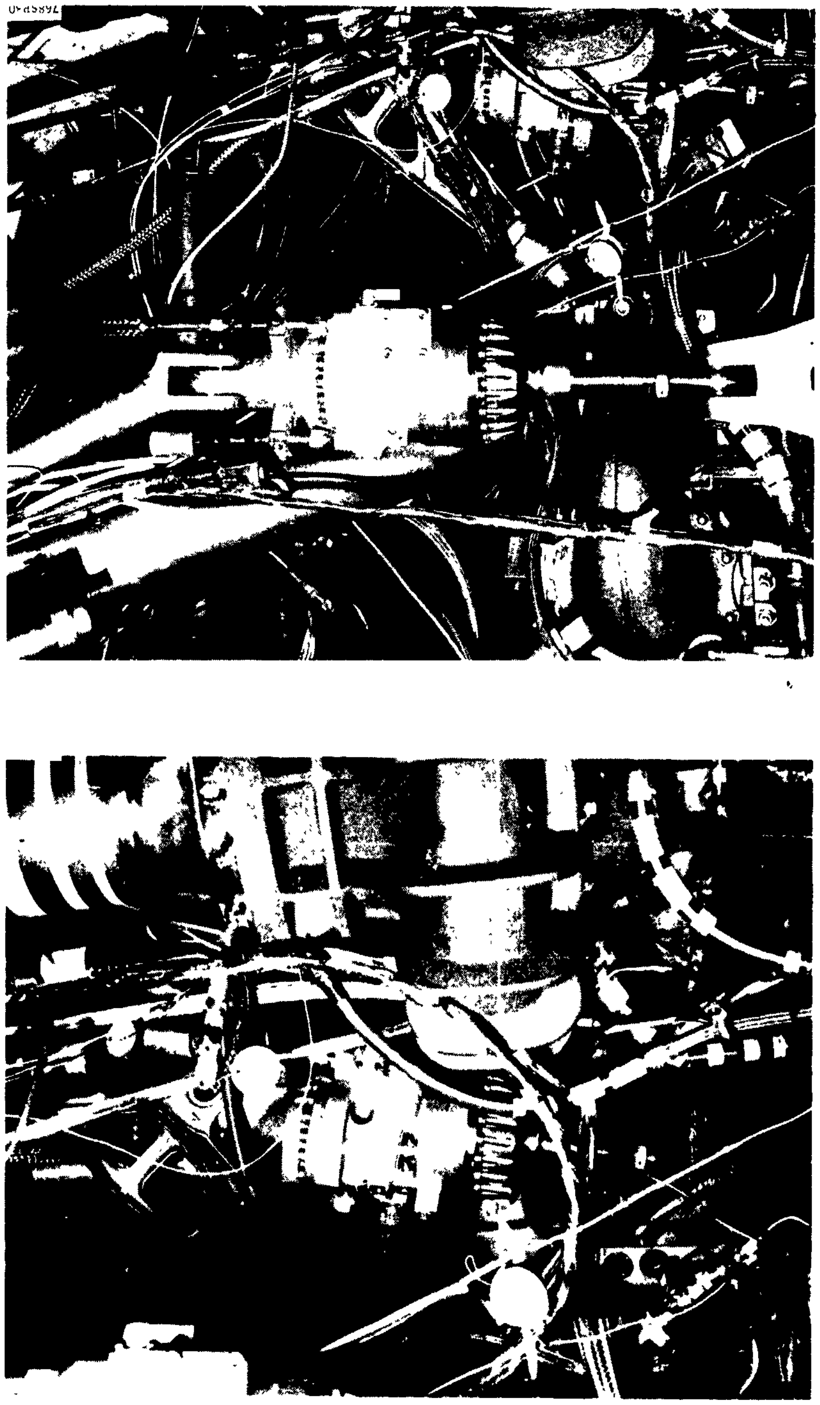


Yaw



Pitch

Figure 20 -- Martin 10-sq in. Actuators, S/A1



Yaw

Pitch

Figure 20 (cont.) -- Martin 10-sq in. Actuators, S/A1

2.5, Narrative of Testing (cont.)

No new weld cracks were noted; however, the slot on one baffle tip propagated from three holes to eight holes.

Leakage through the crack in tube No. 64 of chamber S/N 017 was still too slight to measure.

Following normal servicing procedures, balance changes and replacement of the injector-to-chamber Raco seals, the engine was accepted for retest.

Test No. -214

This was a satisfactory peripheral evaluation test for 201.013 seconds duration. The engine was equipped with 12:1 ablative nozzle extensions using altered 15:1 Refrasil insulation panels, Martin supplied gimbal actuators (10-sq in.) and three flight instrumentation transmitters. The actuators are shown in Figure 20.

Additional baffle weld cracks occurred on both injectors. The engine was returned to the manufacturing area and weld repairs were made to the injectors. The crack previously noted in tube No. 64 of combustion chamber S/N 017 had worsened but the chamber was approved for firing.

Following normal servicing procedures balance changes, injector repairs and replacement of injector-to-chamber Raco seals, the engine was accepted for retest.

Test No. -215

This was a satisfactory Peripheral Evaluation test for 200.458 seconds duration. For this test the engine was equipped with 15:1 ablative skirts and Refrasil insulation panels, Martin POGO fuel accumulators, Martin fuel

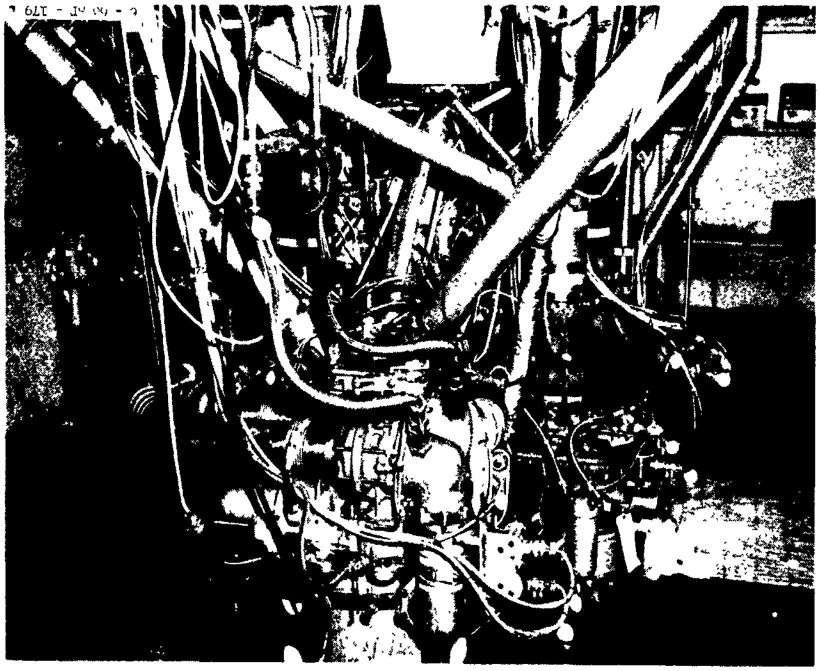


Figure 21 -- Engine S/N 15 -- TC Valves

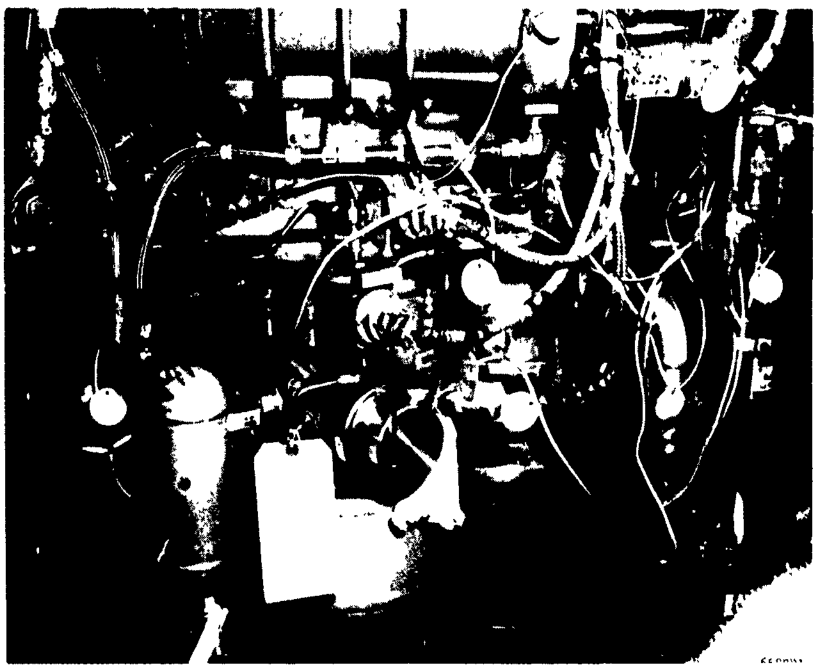


Figure 22 -- Engine S/N 15 -- Gearbox and Lube System

2.5, Narrative of Testing (cont.)

prevalves and three flight instrumentation transmitters. In addition, a low pressure drop fuel check valve was installed on the gas generator assembly of Subassembly 1 and a cavitation suppressant orifice in the fuel bootstrap system of Subassembly 2.

All test objectives were achieved with the exception of suppressing cavitation in the fuel bootstrap system of Subassembly 2.

There was no apparent or additional damage observed on the engine.

Minimum postfire procedures were conducted and, after cleaning, the engine was returned to the Manufacturing Area for inspections, disassembly and formal display.

2.5.2 Engine S/N 15

Figures 21 through 30 show various views of the engine and principal components as installed at Test Stand G-2 prior to the first firing.

Test No. -301

The initial test of Engine S/N 15 was a satisfactory adjustment test for 20.6 sec duration. There were no anomalies noted during operation of the engine or following the test. With exception of engine mixture ratio (MRE) and thrust (F) on subassembly 2, all primary and secondary performance parameters were within specification limits (CEI 005002A, Tables I-A and I-B).

Following routine postfire procedures, engine balance adjustments, and replacement of the injector-to-chamber Raco seals, the engine was accepted for the next test.

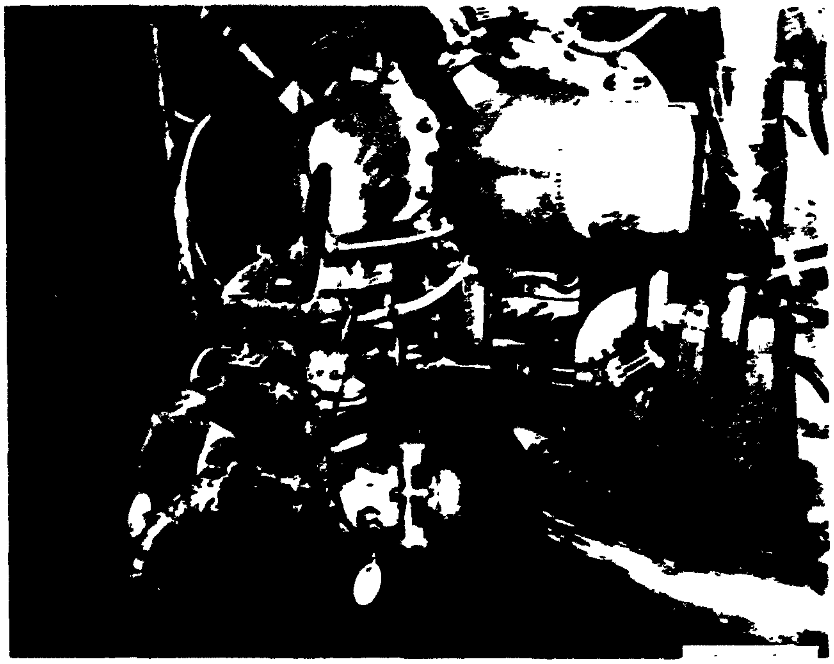


Figure 23 -- Engine S/N 15 -- Yaw Clevis; Torus Inlet

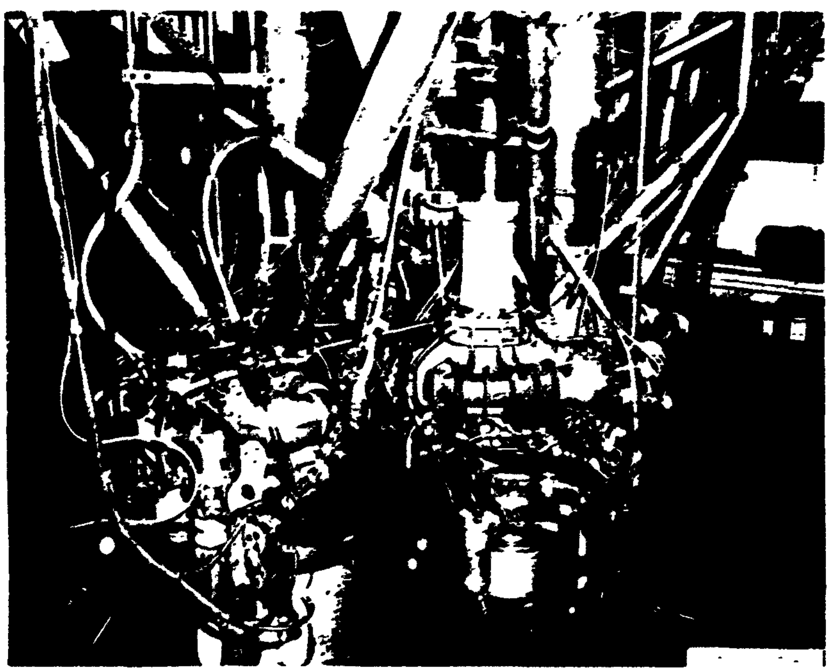


Figure 24 -- Engine S/N 15 -- TCA, S/A2; TPA, S/N1

2.5, Narrative of Testing (cont.)

Test No. -302

This was a satisfactory performance evaluation test for 201.0-sec duration. All primary and secondary performance parameters were within the specification limits. There were no anomalies observed during the test.

The postfire visual inspection revealed a small amount of foreign residue in each of four baffles on injector S/N 699, Subassembly 1. Inspection of the engine and test stand filters failed to disclose the source or the presence of additional contaminants. The injector was removed and back-flushed with the finding only minute particles of ferric nitrates. These particles were believed to have originated in the hydrotest facility, since none was found in the engine or test stand filters.

Combustion chamber S/N 022, Subassembly 2,was slightly eroded at the forward flange above tube No. 6. The erosion was very minor and the chamber was acceptable for retest without rework. Review of the test records and subsequent checks disclosed a failure of the turbine speed (N_t) probe, S/N 764 on Subassembly 2. The probe was replaced. The injector-to-chamber Raco seals were also replaced following postfire leak checks.

Test No. -303

This was a satisfactory performance evaluation test for 200.3 sec duration with all primary and secondary performance parameters within the specification limits. There were no anomalies observed during the test.

The postfire visual inspection gain revealed foreign residue in one baffle tip of each injector. Again, inspection of the engine and test stand filters failed to reveal the source of the contamination or presence of additional contaminants. The discrepancy was classified as minor and the engine was accepted for retest.

2.5, Narrative of Testing (cont.)

The injector-to-chamber Raco seals were replaced following postfire leak checks.

Test No. -304

This was a satisfactory performance evaluation test for 200.8 sec duration. All primary and secondary performance parameters were within the specification limits. There were no anomalies observed during the test.

The postfire leak checks revealed slight leakage through the braid at both ends of the fuel bootstrap line, S/N 542, on Subassembly 2. The leakage was so small that no effect on the test could be determined. The postfire visual inspection again disclosed traces of foreign residue in the baffles of both injectors, but this was considered of minor significance and the injectors were accepted for retest.

Both second-stage turbine nozzles, S/N 662 and S/N 333, had exceeded 800 sec of accumulated testing (time/cycle limitation) and were replaced with S/N 659 and S/N 666 on subassemblies 1 and 2, respectively. The injector-to-chamber Raco seals were replaced following postfire leak checks.

Test No. -305

This was a satisfactory performance evaluation test for 200.6-sec duration. Ablative skirts with Refrasil insulation panels were installed on the thrust chambers and the chambers were gimballed during the test. All primary and secondary performance parameters were within the specification limits with the exception of the thrust of subassembly 2. There were no anomalies observed during the test.

2.5, Narrative of Testing (cont.)

Cracks of varying lengths were found in the base welds of the baffles on both injectors. Injector S/N 699 on Subassembly 1 showed cracks in four baffles. There were cracks in six baffles in injector S/N 698 on Subassembly 2. Both injectors were removed and repaired. Combustion chambers S/N 021 and S/N 022, on Subassemblies 1 and 2, respectively, had leaks at the forward flange joints on the inside periphery. Both were removed for torch-braze repairs.

Turbine seal leakage on Subassembly 2 was 1200 cc/min, which exceeded the allowable maximum of 750 cc/min. Turbopump assembly S/N 011 was removed for rework of the seal.

During the postfire activities both ablative skirts were damaged by inadvertent gimbal operation. The outer skins were dented when the nozzles collided.

The injector-to-chamber Raco seals were replaced following postfire leak checks.

Test No. -306

This was a satisfactory performance evaluation test for 200.7-sec duration. All primary and secondary performance parameters were within the specification limits with the exception of the thrust on Subassembly 1. The engine operation was normal during the test and no anomalies were observed.

Leakage occurred on both combustion chambers at the tube-to-forward flange joint. The leakage was minor and the chambers were accepted for subsequent testing.

The injector-to-chamber Raco seals were replaced following postfire leak checks.

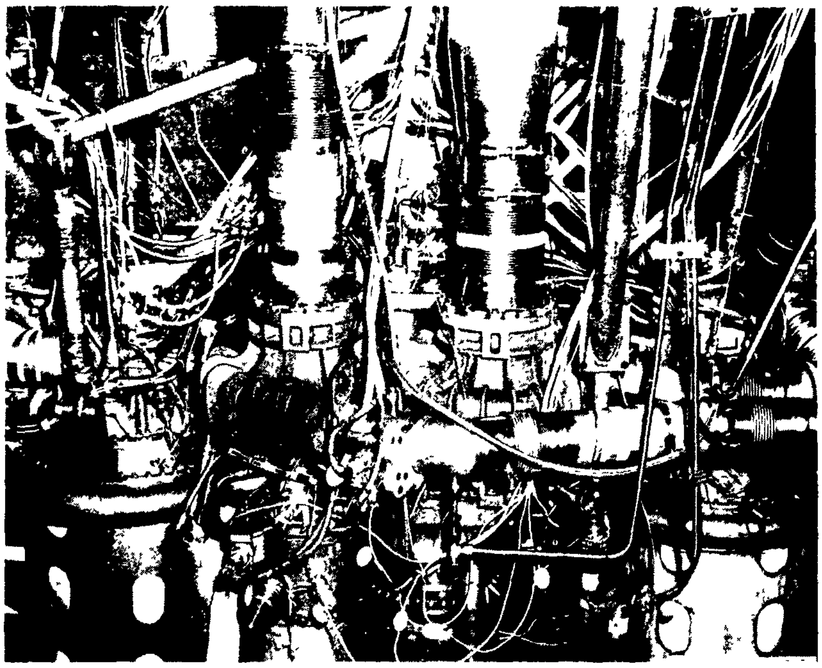


Figure 25 -- Engine S/N 15 -- Inlet Lines and TPA, S/A 1

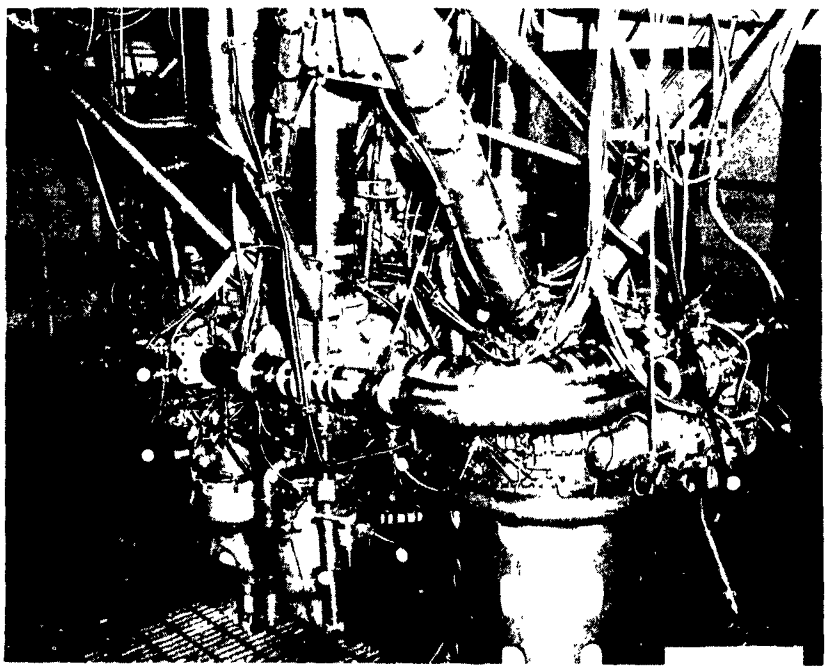


Figure 26 -- Engine S/N 15 -- Upper Section

2.5, Narrative of Testing (cont.)

Test No. -307

This was a satisfactory net positive suction head (NPSH) evaluation test for 200.470-sec duration. Ablative skirts and refrasil insulation panels were installed and the thrust chambers were gimbaled. Shortly before the engine test, the expulsion test of exit closures S/N 006 and S/N 005 on Subassemblies 1 and 2, respectively, was conducted satisfactorily. All test objectives were attained. Engine performance responded properly to the variations in NPSH at the pump inlets.

The NPSH objectives were attained by manipulation of the tank pressures early in the test to provide a minimum oxidizer NPSH of 44 ft concurrently with a minimum fuel NPSH of 43 ft; then, while lowering the oxidizer NPSH to approximately 35 ft, the fuel suction pressure was increased to a nominal run condition.

Ablative skirt S/N 021 on Subassembly 1 was slightly eroded at one location on the inside periphery of the upper mating flange.

Leakge occurred again on both combustion chambers at the tube-to-forward flange joints and was in the same general area as noted on previous tests, but had not increased; thus it was accepted and subsequent testing was conducted.

Leakage occurred through the oxidizer pump seals of both TPA S/N 009 and TPA S/N 011 on Subassemblies 1 and 2, respectively. The leakage was excessive and could not be accurately measured; however, the turbopumps were accepted for subsequent testing despite the leakage.*

The injector-to-chamber Raco seals were replaced with experimental solid-spring Raco seals.

*With Air Force approval to expedite testing. The condition was considered safe and the seals were due for scheduled replacement after two more tests.

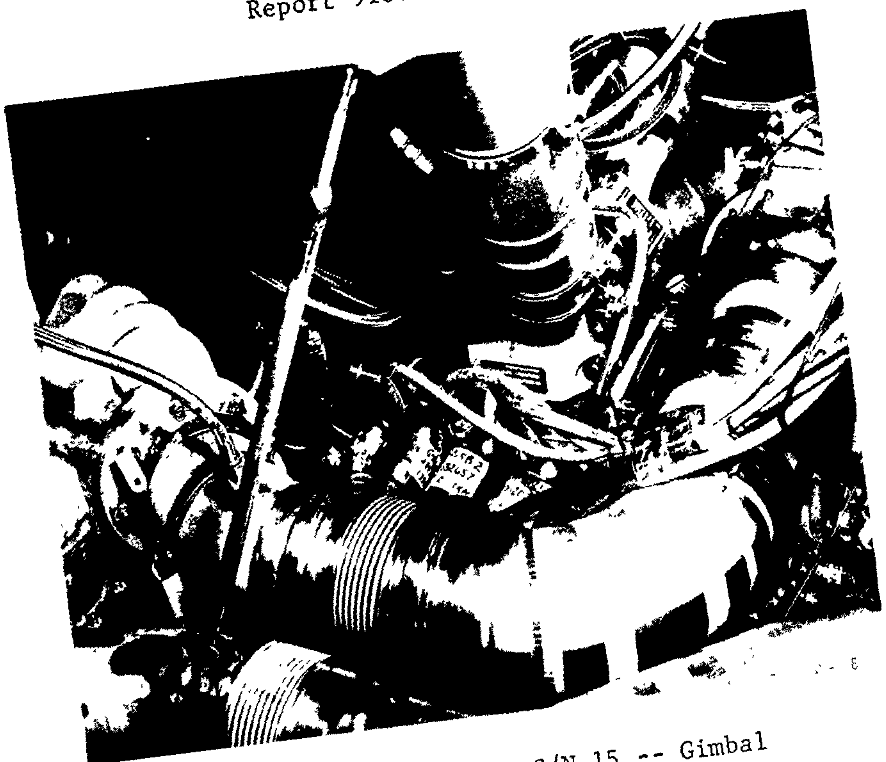


Figure 27 -- Engine S/N 15 -- Gimbal

Figure 28 -- Engine S/N 15 -- Gas Generator Valves

2.5, Narrative of Testing (cont.)

Test No. -308

This was a satisfactory adjustment test for 20.977-sec duration. The engine was equipped with Martin fuel prevalves, flight instrumentation pressure transmitters, and experimental Raco seals (injector-to-chamber). With the exception of the excessive leakage and vapors from the oxidizer pump seals, engine operation was normal. No additional hardware discrepancies were noted.

Leakage was again noted on both combustion chambers at the tube-to-flange joint but had not increased and the chambers were accepted for retest. Likewise, both oxidizer pump seals were still leaking excessively but were accepted for retest.

The experimental injector-to-chamber Raco seals were not disturbed following this test.

Test No. -309

This was an unsatisfactory peripheral test for 2.5-sec duration. The test was manually terminated because S/A 1 failed to complete the start transient. There was no damage to the engine.

Malfunction of the pressure sequence valve override solenoid (PSVOR) prevented opening of the thrust chamber valves on Subassembly 1. Consequently the turbopump operated only in a "dead-headed" condition until the start cartridge expired. Subassembly 2 started in a normal manner.

The PSV was replaced and minimal postfire procedures were conducted prior to the next test.

2.5, Narrative of Testing (cont.)

Test No. -310

This was a satisfactory peripheral evaluation test for 200.3-sec duration. This test had the same objectives and test conditions as the previous test which malfunctioned when Subassembly 1 failed to complete the start transient. The engine was equipped with Martin fuel prevalves, POGO fuel accumulators, experimental Raco seals, and flight instrumentation pressure transmitters. Engine operation was normal through the transients and steady state with exception of the excessive leakage through the oxidizer pump seals.

Leakage was again noted at the tube-to-flange joint on both combustion chambers. An additional leak was noted through a crack in tube No. 25 approximately 1 in. below the flange. Both oxidizer pump seals continued to leak excessively.

Following completion of the postfire procedures, the engine assembly was shipped to the manufacturing area for inspection and repairs. The turbopump assemblies were disassembled and the first-stage turbine rotors and second-stage nozzles were replaced and the oxidizer pump seals were repaired. In addition, the PSVOR on Subassembly 2 was removed for inspection and replacement.

The experimental injector-to-chamber Raco seals were replaced with the standard seals used on earlier tests.

The engine was returned to the Test Area on 12 September for continuation of the test program.

2.5, Narrative of Testing (cont.)

Test No. -311

This was a satisfactory adjustment test for 21.3-sec duration. The engine was equipped with Martin fuel prevalves and flight instrumentation pressure transmitters. There were no anomalies observed during the test.

Leakage was again noted on both combustion chamber forward flanges and through the crack in tube No. 25 of combustion chamber S/N 022. The engine was accepted for further testing without correction of the leakage.

The injector-to-chamber Raco seals were replaced following postfire leak checks.

Test No. -312

This was a satisfactory peripheral evaluation test for 201.1-sec duration. The engine was equipped with Martin fuel valves, POGO fuel accumulators, and flight instrumentation pressure transmitters. There were no anomalies observed during the test.

Leakage was again noted on both combustion chamber forward flanges and through the crack in tube No. 25 of combustion chamber S/N 022 on Subassembly 2.

The injector-to-chamber Raco seals were replaced following the postfire leak checks.

Test No. -313

This was a satisfactory adjustment test for 20.8-sec duration. The engine was equipped with Martin fuel prevalves and special POGO instrumentation

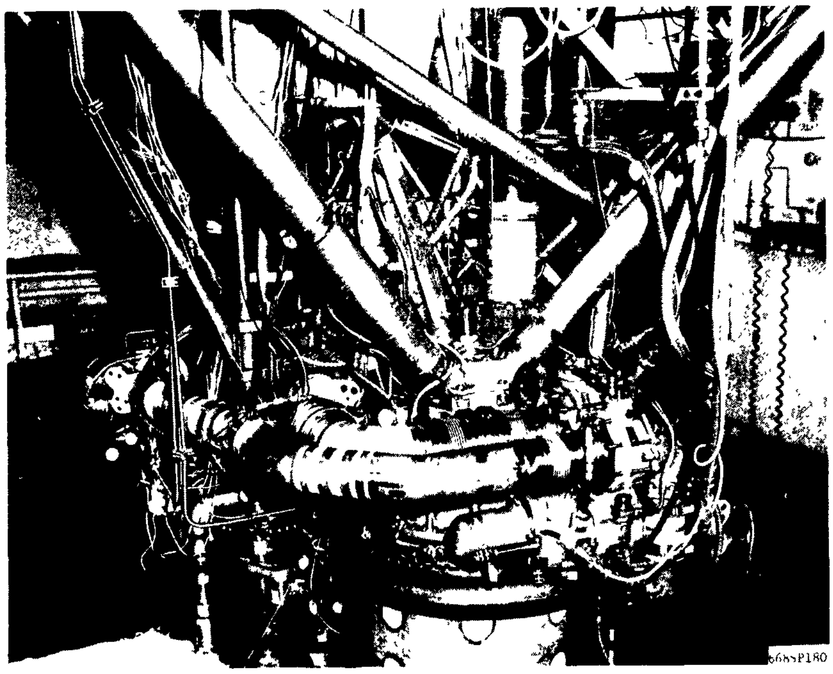


Figure 29 -- Engine S/N 15 -- Frame and Discharge Lines

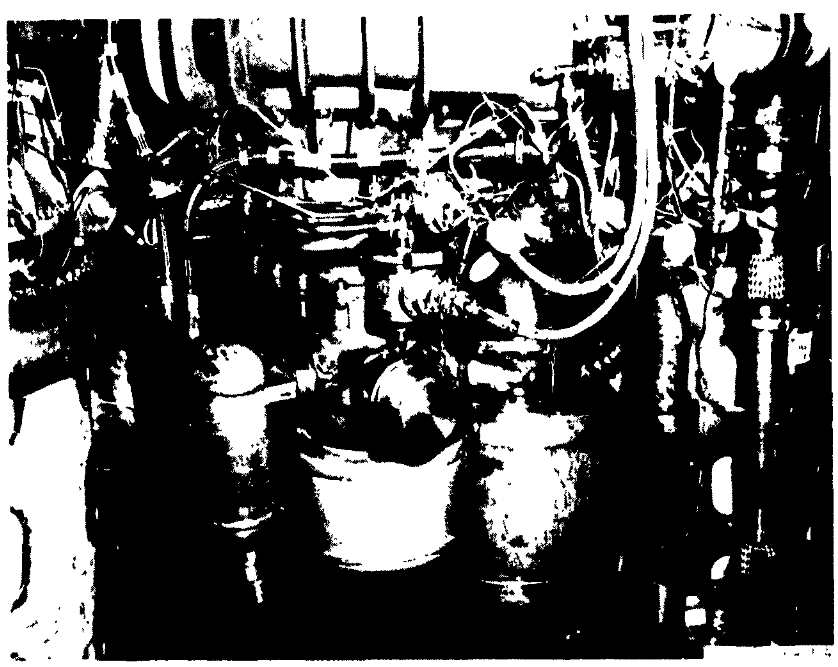


Figure 30 -- Engine S/N 15 -- Gearbox and Lube System

2.5, Narrative of Testing (cont.)

transmitters. The engine was operated at high fuel suction pressures (50 - 55 psia). There were no anomalies observed during the test.

Leakage was again noted on both combustion chamber forward flanges and through the crack in tube No. 25 of combustion chamber S/N 022. The chamber was removed and the crack was repaired to reduce the total chamber leakage.

Each injector had one small base weld crack in a baffle. The cracks were within acceptable limits and the injectors were approved for subsequent testing.

The injector-to-chamber Raco seals were replaced following the post-fire leak checks.

Test No. -314

This was a satisfactory peripheral evaluation test for 200.9-sec duration. The engine was equipped with Martin fuel prevalves, POGO fuel accumulators, and special POGO instrumentation. In addition, a fuel suction pressure excursion was performed successfully. There were no anomalies observed during the test.

Leakage was again noted on both combustion chambers at the forward flange joints. The chambers were accepted for subsequent testing.

Cracks were noted in baffle base welds on both injectors. Injector S/N 699 Subassembly 1, had cracks in six baffle welds; injector S/N 698, Subassembly 2, had cracks in two baffle welds. The injectors were accepted with the cracks and retesting was conducted.

2.5, Narrative of Testing (cont.)

Turbine seal leakage on TPA S/N 011, Subassembly 2, measured 2000 cc/min, which exceeds the allowable maximum of 750 cc/min. This was the second incident of leakage through this seal, S/N 4869. The seal was accepted.

The injector-to-chamber Raco seals were replaced following postfire leak checks.

Test No. -315

This was a satisfactory adjustment test for 21.0 sec duration. The engine was equipped with Martin fuel prevalves, flight instrumentation pressure transmitters and a cavitation suppressant orifice in the fuel bootstrap line of Subassembly 2. The start transient and steady state phases of the test were normal. During the shutdown transient, the turbine inlet temperature (T_{Ti}) on Subassembly 2 exceeded 1700°F for approximately 8.5 sec. (Maximum allowable time is 2.0 sec.) Waiver of a turbine inspection was obtained for the one remaining test.

The gas generator oxidizer check valve on Subassembly 2 had 12,000 cc/min leakage in the reverse direction. The valve was removed, disassembled, reassembled, and the leak check performed successfully without discovery of the cause for its previous leakage. The valve was reinstalled on the engine.

Cracks were found on both combustion chambers in the lower weld seams where the steel reinforcing shells are attached to the bands. The cracks were repaired by welding and the chambers accepted for retest.

Combustion chamber S/N 022, Subassembly 2, had a pinhole leak on the outside of tube No. 123 in the weld at the aft wire-lock band. The chamber was repaired. Leakage was again noted in both chambers at the forward flange joints. The chambers were accepted for the final test.

2.5, Narrative of Testing (cont.)

Cracks again were noted on both injector baffle welds but they had not increased significantly and the injectors were accepted for retest.

The injector-to-chamber Raco seals were replaced following postfire leak checks.

Turbine seal leakage was zero on TPA S/N 011. The leakage had measured 2000 cc/min prior to the test.

Test No. -316

This was a satisfactory peripheral evaluation test for 200.8-sec duration. Ablative skirts and Refrasil insulation panels installed and the engine was gimballed. POGO fuel accumulators, 15:1 Martin fuel prevalves, and a cavitation suppressant orifice in the Subassembly 2 bootstrap line were also installed on this test. Shortly before the engine test, an expulsion test of exit closures S/N 007 and 008, on Subassemblies 1 and 2, respectively, was conducted. All test objectives were successfully attained.

A small fire was observed during the latter portion of the test near the lube oil reservoir on Subassembly 2. Subsequent reviews of motion picture revealed ignition of fuel from the pump seal cavity drain which is in proximity to the reservoir. The seal leakage was later verified.

The Refrasil insulation on both assemblies had sustained damage during the test; however, the ablative skirts were not affected. Two panels on Subassembly 2 separated at the lower end of the seam between the chambers and were wrinkled. Two similar sections on Subassembly 1 were severely scorched by heat and had slight erosion on the lower edges. The exit closure flanges of both nozzles were eroded slightly in the same locations.

2.5, Narrative of Testing (cont.)

Minimum postfire procedures were conducted and, after cleaning, the engine was returned to the manufacturing area for inspections, disassembly, and formal display.

2.5.3 Daily Test Log

A chronological account of the specific activities and events associated with each test are presented in Appendix C.

Tables 1 and 2 of Appendix C present a tabulation of the TPA servicing for engine S/N 14 and S/N 15 respectively.

3. Data and Component Evaluations

3.1 Engine Performance

3.2 Engine Components

3.3 Thrust Chamber Assembly Components

3.4 Turbopump Assembly Components

3.5 Engine Controls

3. DATA AND COMPONENT EVALUATIONS

3.1 ENGINE PERFORMANCE

The test objectives for the Titan IIIM Stage I Engine Demonstration Program are defined in SSD-CR-65-8180-140, the System Test Implementation Plan. The principal objective was to test two Stage I engines assembled from new prototype hardware to demonstrate performance and repeatability at nominal conditions and operation at peripheral flight conditions. The nominal performance evaluation phase consisted of six tests on each engine in order to determine mixture ratio repeatability, thrust growth characteristics, and autogenous system performance, and to demonstrate thrust capability and specific impulse. The peripheral test phase consisted of nine tests on each engine, including one minimum NPSH test to determine operation at flight minimum inlet propellant pressures and eight tests to determine engine operating capability at "worst flight" conditions* for the ablative skirt and combustion chamber. The nominal performance evaluation tests and the minimum NPSH tests were also conducted to verify engine performance compatibility with requirements specified in Paragraph 3.1 of the Contract End Item Specification.

3.1.1 Performance Evaluation Tests

Primary Performance

The demonstration test results are shown in Table 10 for comparison with the primary performance requirements as given in the CEI Specification CP 40224, Table I-A. The performance evaluation tests were conducted at nominal inlet conditions following an initial adjustment test. Specific impulse (I_{sp}) is referenced only as an increment (ΔI_{sp}) to the target value and is presented for comparison of test data only without regard for the absolute quantity.

*Most adverse condition occurring during flight when the engine balance (thrust and mixture ratio) is within specification for sea level testing.

Table 10 -- Primary Performance, Titan IIIM Demonstration Engines

	Duration, sec	Engine Thrust, lb	Specific Impulse, sec	Mixture Ratio (MRe)	Subassembly Thrust, lb SA 1	SA 2
CEI Requirements						
Maximum	--	535,600		1.948	267,800	267,800
Nominal	--	520,000		1.910	260,000	260,000
Minimum	200	504,400		1.782	252,200	252,200
Engine S/N 14						
Test Series No.			Calculated Delta, I_{sp}, sec			
-202(2)	200.8	507,884	3.5	1.934	253,253	254,632
-203	200.6	508,917	3.1	1.928	252,395	256,522
-204(3)	114.0	514,434	3.1	1.920	253,801	260,633
-205(1)(2)	20.8	513,664	2.4	1.948	257,424	256,240
-206(2)	200.9	519,288	2.7	1.923	262,114	257,174
		Avg.	3.0			
Engine S/N 15						
-302(2)	201.0	527,186	2.9	1.912	264,363	262,823
-303	200.3	530,772	3.0	1.902	266,024	264,749
-304	200.8	532,360	3.1	1.901	267,060	265,300
-305	200.6	535,416	3.1	1.900	267,435	267,982
-306	200.7	536,086	2.9	1.905	268,512	267,575
		Avg.	3.0			

Time Period: 2 sec - FS_2
Data corrected to standard inlet conditions, 15:1 nozzle and altitude (vacuum).

(1) Adjustment test - TPA replacement on SA 2.
(2) Pre-test balance change.
(3) Pre-test S/A 2 combustion chamber replacement.

3.1, Engine Performance (cont.)

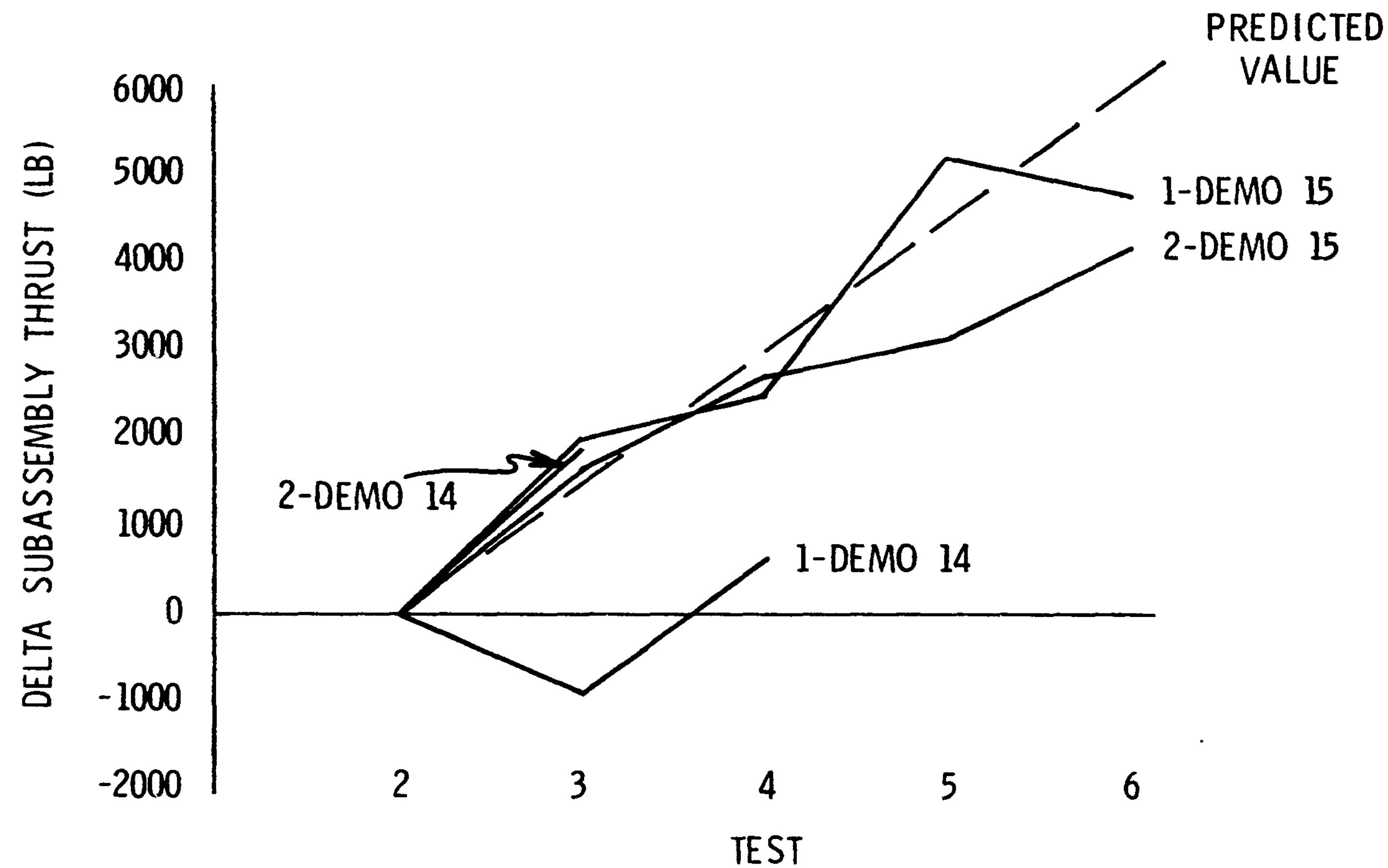
As shown in Table 10, the primary performance parameters (engine thrust, specific impulse, mixture ratio, and subassembly thrust) for engine S/N 14 were within specification limits. The engine S/N 14 series includes one test terminated after 115 seconds operation because of a TPA failure. This necessitated a posttest TPA replacement, one 20-second adjustment test, and the subsequent necessary engine balance changes. The combustion chamber on Subassembly 2 was replaced prior to Test No. -204 as noted in Table 10.

The primary performance parameters for engine S/N 15 were within specification limits with the exception of the values for subassembly thrust during Test Nos. -305 and -306 and for engine thrust during Test No. -306. These values exceeded the upper thrust limit because of normal thrust growth and were predicted and predeclared. The series of five consecutive, nominal, full duration tests were conducted on engine S/N 15 with no major hardware or balance changes between tests subsequent to the initial balance test.

Thrust Growth

Figure 31 illustrates the thrust growth that occurred during the performance evaluation tests. Only those tests are shown that were conducted without hardware changes or balance adjustments that would affect the natural thrust growth characteristic. The predicted growth rate of 1500 lb thrust per subassembly per test is shown for comparison, and is the value that will be used for Titan IIIM flight predictions.

Because of the hardware and balance changes between tests only three tests with engine S/N 14 were applicable to the evaluation of thrust growth As shown in Figure 31, Subassembly 1 of engine S/N 14 shows a thrust growth similar to that of engine S/N 15, whereas Subassembly 2 thrust decreased during Test No. 205 and increased during the following test. An occasional random



NOTE: 2 sec-FS_2 data, corrected to standard inlet conditions

Figure 31 -- Thrust Growth, Titan IIIM Demonstration Engines

3.1, Engine Performance (cont.)

decrease in thrust is to be expected and has occurred on several engines during other Titan programs. The engine S/N 14 tests shown in Figure 31 were conducted with the 112-blade turbine rotor design, P/N 1130983-1.

The tests with engine S/N 15 were sufficient in number to show a definite trend of increasing thrust and show that the predicted growth of 1500 lb subassembly thrust per test is representative for Titan IIIM engines. The tests with engine S/N 15 were conducted with the new 83-blade turbine rotor design, P/N 1154950-1.

Mixture Ratio Repeatability

Three tests with engine S/N 14 and five tests with engine S/N 15 provided mixture ratio repeatability data. Table 11 is a tabulation of corrected mixture ratios for three tests, Nos. -201, -202 and -203, with engine S/N 14. These were the only tests of the nominal performance series that did not have hardware or balance changes between tests that would affect engine mixture ratio characteristics. The sample from engine S/N 14 was too small for significant repeatability evaluation, but the values of Δ MRE appear similar to the larger sample obtained from engine S/N 15 shown in Table 12. The standard deviation of engine mixture ratio for engine S/N 15 was ± 0.005 during tests, Nos. -302 through -306, both for the 2-20 second time intervals and for the 2-200 second time intervals. The 3σ value of ± 0.015 was within the CEI Specification value of ± 0.024 (not a demonstration requirement).

Specific Impulse Repeatability

Table 13 is a tabulation by subassembly of corrected specific impulse values attained during the performance evaluation test series. The table shows a comparison of the performance levels of the two Demonstration engines

Table 11 -- Mixture Ratio Repeatability -- Engine S/N 14

Test No.	1-MRSA	Test-Test Delta 1-MRSA	2-MRSA	Test-Test Delta 2-MRSA	MRE	Test-Test Delta MRE
2-20 sec data						
-201	1.9144		1.9311		1.9226	
		+0.0211		+0.0045		+0.0130
-202	1.9355		1.9356		1.9356	
		+0.0179		-0.0256		-0.0042
-203	1.9534		1.9100		1.9314	
2-200 sec data						
-202	1.9318		1.9355		1.9336	
		+0.0187		-0.0292		-0.0056
-203	1.9505		1.9063		1.9280	

Data corrected to standard inlet conditions.

Table 12 -- Mixture Ratio Repeatability -- Engine S/N 15

2-20 second data

Test No.	1-MRSA	Test-Test Delta 1-MRSA	2-MRSA	Test-Test Delta 2-MRSA	MRE	Test-Test Delta MRE
-302	1.9294		1.8901		1.9097	
		-0.0146		+0.0016		-0.0064
-303	1.9148		1.8917		1.9033	
		-0.0002		-0.0008		-0.0005
-304	1.9146		1.8909		1.9028	
		-0.0016		-0.0032		-0.0025
-305	1.9130		1.8877		1.9003	
		+0.0141		+0.0096		+0.0119
-306	1.9271		1.8973		1.9122	
Average	1.9198		1.8915		1.9057	
Std. Deviation (1 sigma)	0.0078		0.0035		0.0050	
Three sigma	0.0234		0.0106		0.0151	

2-200 second data

Test No.	1-MRSA	Test-Test Delta 1-MRSA	2-MRSA	Test-Test Delta 2-MRSA	MRE	Test-Test Delta MRE
-302	1.9293		1.8956		1.9124	
		-0.0154		-0.0049		-0.0102
-303	1.9139		1.8907		1.9022	
		-0.0002		-0.0021		-0.0011
-304	1.9137		1.8886		1.9011	
		-0.0014		-0.0006		-0.0010
-305	1.9123		1.8880		1.9001	
		+0.0072		+0.0043		+0.0058
-306	1.9195		1.8923		1.9059	
Average	1.9177		1.8910		1.9043	
Std. Deviation (1 sigma)	0.0070		0.0030		0.0050	
Three sigma	0.0210		0.0091		0.0150	

Data corrected to standard inlet conditions.

Table 13 -- Specific Impulse Repeatability, Titan IIIM Demonstration Engines

Test Series No.	Delta ISPSA SA 1, sec	Delta ISPSA SA 2, sec	Delta I_{sp} Engine, sec
Engine S/N 14			
-202	4.33	2.62	3.48
-203	3.76	2.52	3.14
-204	4.16	2.08	3.12
-205	3.42	1.42	2.42
-206	4.04	1.34	2.69
Average	3.94	2.00	2.97
Standard Deviation (1 sigma)	±0.36	±0.60	±0.42
Engine S/N 15			
-302	3.41	2.46	2.94
-303	3.53	2.41	2.97
-304	3.45	2.68	3.07
-305	3.46	2.66	3.06
-306	3.09	2.62	2.86
Average	3.39	2.57	2.98
Standard Deviation (1 sigma)	±0.17	±0.12	±0.09

Data corrected to standard inlet conditions.
Data time period: 2 sec - FS_2.

3.1, Engine Performance (cont.)

and four subassemblies, together with the test-to-test variances, for five successive tests under nominal acceptance test conditions.

The test-to-test variations in I_{sp} shown in Table 13 are of interest particularly for the case of the engine S/N 15 performance series. There were five consecutive full duration tests with engine S/N 15 at nominal inlet conditions with no major hardware or balance changes. Test-to-test data of this statistical quality is rarely obtained, and may remain as the only such sample in the Titan IIIM program. In this series the 1σ variance in engine I_{sp} was ± 0.09 second. The engine S/N 14 series had a larger variance, ± 0.42 second, with an undetermined portion of this variance caused by variables introduced by the TPA failure during Test No. -204, the 20-second adjustment Test No. -205, and the mixture ratio balance adjustment before Test No. -206.

Table 14 shows thrust chamber specific impulse for the entire series of Demonstration tests, including the tests conducted at peripheral conditions of thrust, mixture ratio, and propellant inlet conditions, all of which affect I_{sp}. Specific impulse for the thrust chambers, I_{sptc}, rather than for the engines or subassemblies, was selected for comparing the full series of tests, because this parameter can be normalized directly to nominal thrust chamber conditions.

Corrected I_{sptc} (corrected only to standard engine inlet conditions) is also shown for comparison with the normalized values. Normalized I_{sptc} data from individual tests on a subassembly basis appear to differ slightly from the corrected data, but based on the average of four subassemblies (bottom of Table 14), the two methods yield almost identical data. The average of both corrected and normalized I_{sptc} values for all Demonstration tests is therefore ± 5.22 seconds. This value for thrust chamber I_{sp} can be adjusted to an approximately equivalent engine or subassembly I_{sp} by subtracting nominal loss due to turbine operation, which is 2.2 seconds (Reference 3). The net average ΔI_{sp}

Table 14 -- Thrust Chamber Specific Impulse, Titan IIIM Demonstration Engines

Corrected data are corrected to standard engine inlet conditions, 15:1 nozzle, and vacuum (altitude) exhaust conditions.
Normalized data are normalized to nominal thrust chamber conditions (MRTC 1.99, T_p 68°, P_c 808 psia), 15:1 nozzle, and vacuum exhaust conditions.
Time period: 2 sec - FS_2

		Engine S/N 14			
		Subassembly One		Subassembly Two	
Test Plan No.	Test Series No.	Delta ISPTC Corrected	Delta ISPTC Normalized	Delta ISPTC Corrected	Delta ISPTC Normalized
1	-201	7.21	7.27	5.62	6.13
2	-202	6.57	6.91	4.93	5.44
3	-204	6.40	6.68	4.40	4.37
4	-203	5.98	6.56	4.85	4.85
5	-205	5.82	6.38	3.82	4.51
6	-206	6.46	6.54	3.75	4.00
7	-207	4.94	4.68	3.56	4.41
8	-208	6.67	6.88	3.63	4.87
9	-215	4.62	4.84	2.66	3.91
10	-211	7.52	6.42	4.38	3.44
11	-212	6.26	5.41	2.24	2.42
12	-213	6.18	5.96	3.25	3.26
13	-214	5.55	5.83	1.68	2.65
14	-209	7.02	5.75	3.04	1.99
15	-210	6.22	4.93	3.89	2.95
Average Delta ISPTC		6.23	6.07	3.71	3.95
Test-Test Variance, 1 sigma		±0.78	±0.81	±1.05	±1.16

Average of Four Subassemblies:	Corrected
ISPTC	5.22 sec
T-T Variance	±0.80 sec

Table 14 (cont.)

Test Series No.	Engine S/N 15 Subassembly One Delta ISPTC Corrected	Subassembly One Delta ISPTC Normalized	Subassembly Two Delta ISPTC Corrected	Subassembly Two Delta ISPTC Normalized
-301	6.41	6.74	4.46	5.46
-302	5.80	5.88	5.00	4.83
-305	5.85	5.62	5.19	4.82
-303	5.92	5.73	4.94	4.66
-304	5.84	5.62	5.21	4.88
-306	5.48	5.34	5.16	4.88
-307	5.63	4.82	4.01	3.82
-315	6.63	7.06	4.25	5.26
-316	7.33	7.53	4.05	5.17
-308	6.71	5.59	5.45	5.13
-310	6.07	5.61	4.52	4.56
-311	6.27	6.52	4.08	4.91
-312	5.49	6.16	2.98	4.46
-313	7.45	6.33	5.82	4.79
-314	7.00	6.16	5.20	4.55
	6.26	6.05	4.69	±4.81
	±0.64	±0.70	±0.73	±0.39

Normalized

5.22 sec
±0.77 sec

Table 15 -- Measured Thrust, Titan IIIM Demonstration Engines

(Test Stand G-2)

2 sec - FS_2 data, corrected to standard inlet conditions, 15:1 nozzle, and vacuum (altitude) exhaust conditions.

Test Series No.	Calculated F_{engine}, lb	Calculated Delta ISPE, sec	Measured Thrust F_{engine}, lb	Measured Thrust Delta ISPE, sec	Difference (Calc-Meas) F_{eng}, lb	Difference (Calc-Meas) ISPE, sec	Percentage Difference, (Calc-Meas)/Calc, %
Engine S/N 14							
-201	510,470	4.1	506,095	1.5	-4375	-2.6	-0.9
-202	507,884	3.5	504,492	1.4	-3392	-2.1	-0.7
-203	(No measured thrust)						
-204	514,434	3.1	510,557	0.8	-3877	-2.3	-0.8
-205	513,664	2.4	510,198	0.4	-3466	-2.0	-0.7
-206	519,288	2.7	516,994	1.4	-2294	-1.3	-0.4
-207	526,754	1.9	526,066	1.5	-688	-0.4	-0.1
-208	545,337	2.6	543,977	1.9	-1360	-0.7	-0.2
209-214	(No measured thrust)						
-215	552,786	1.1	553,721	1.6	+935	+0.5	+0.2
Average		2.7		1.3	-2315	-1.4	-0.4
Standard Deviation (1 sigma)		±0.9		±0.5	±1824	±1.1	±0.4
Engine S/N 15							
-301	510,257	3.0	508,326	1.9	-1931	-1.1	-0.4
-302	527,186	2.9	526,607	2.6	-579	-0.3	-0.1
-303	530,772	3.0	530,170	2.6	-602	-0.4	-0.1
-304	532,360	3.1	530,641	2.1	-1719	-1.0	-0.3
-305	535,416	3.1	531,305	0.7	-4111	-2.4	-0.8
-306	536,086	2.9	533,506	1.4	-2580	-1.5	-0.5
-307	538,210	2.5	534,038	0.2	-4172	-2.3	-0.8
-308	532,342	3.6	531,280	2.9	-1062	-0.7	-0.2
-309	(Short test - no measured thrust)						
-310	531,107	2.8	530,832	2.6	-275	-0.2	-0.1
-311	499,863	2.9	498,857	2.3	-1006	-0.6	-0.2
-312	496,207	2.0	495,744	1.7	-463	-0.3	-0.1
-313	491,654	4.2	490,856	3.7	-798	-0.5	-0.2
-314	495,760	3.7	494,879	3.2	-881	-0.5	-0.2
-315	520,912	2.9	510,447	2.1	-1465	-0.8	-0.3
-316	530,802	3.2	528,844	2.1	-1958	-1.1	-0.4
Average		3.1		2.2	-1573	-0.9	-0.3
Standard Deviation (1 sigma)		±0.5		±0.9	±1226	±0.7	±0.2

3.1, Engine Performance (cont.)

for all tests thus becomes 3.0 seconds, which compares almost exactly with the performance values for the series for both engines (see Table 10).

The average 1σ variance of normalized I_{sptc} (Table 14) for the four Demonstration subassemblies, including all the peripheral tests, was ± 0.77 second. This is comparable to the test-to-test value of ± 0.65 second derived from Titan IIIM thrust chamber development test data (Reference 3).

Measured Thrust

For the engine tests conducted on Test Stand G-2, which were all tests with engine S/N 15, and all tests with engine S/N 14 except Nos. -209 through -214, two values of engine thrust were obtained, with the results shown in Table 15. The "calculated" thrust values were derived according to the method in the CEI Specification, the same method used elsewhere in this report. The "measured" thrust values were determined from data obtained with four load cells installed in the test facility.

The measured thrust shown in Table 15 was less than the calculated thrust, in all cases except for Test No. -215. The average difference was 0.4% for engine S/N 14 and 0.3% for engine S/N 15.

The absolute level of measured thrust on Test Stand G-2 is not considered reliable because calibration of the thrust measuring system was not repeatable. The values obtained are for record only.

Turbine Speed at Rated Engine Thrust

A specific requirement in Paragraph 6.1.1.19 of the Statement of Work specifies engine demonstration test limits for turbine speed as

Table 16 -- Turbine Speed at Rated Thrust, Demonstration Engines

Test Series No.	Time Period	Turbine Speed at Rated Thrust and SIC (Limits: 23,400 to 24,800 rpm) Subassembly 1	Subassembly 2
Engine S/N 14			
-201	2-19.6	23,749	23,855
-202	2-200.8	23,676	23,977
-203	2-200.6	23,621	23,972
-204	2-114.0	23,702	23,909
-205	2-20.9	23,632	23,968
-206	2-200.9	23,556	24,121
-207	2-200.6	23,951	24,087
-208	2-21.2	23,685	23,692
-209	2-20.6	24,295	24,589
-210	2-200.3	24,289	24,559
-211	2-20.7	23,992	24,387
-212	2-201.0	24,014	24,315
-213	2-20.8	23,934	24,175
-214	2-201.0	24,030	24,112
-215	2-200.5	24,020	24,072
Engine S/N 15			
-301	2-20.7	23,568	23,856
-302	2-201.0	23,573	24,080
-303	2-200.3	23,623	24,122
-304	2-200.8	23,598	24,074
-305	2-200.6	23,599	24,097
-306	2-200.7	23,586	24,078
-307	2-200.5	24,080	24,469
-308	2-21.0	23,932	24,132
-309	(Failed to start)	--	--
-310	2-200.4	23,754	24,200
-311	2-21.3	23,752	23,799
-312	2-201.1	23,775	23,897
-313	2-20.8	24,004	24,295
-314	2-200.9	24,116	24,450
-315	2-21.1	23,711	23,809
-316	2-200.8	23,720	23,823

3.1, Engine Performance (cont.)

24,200 + 600, -800 rpm, using data from the 2 second to FS2 time interval corrected to rated engine thrust and standard inlet conditions. This corrected turbine speed parameter has been summarized in Table 16 for all the Demonstration tests. The values are all within the specified limits.

3.1.2 Peripheral Tests

Target and Actual Test Conditions

Beginning with the eighth test of each Demonstration engine, succeeding tests were conducted at peripheral conditions of thrust, mixture ratio, and propellant inlet temperatures and pressures. The tests were designed to demonstrate the structural integrity of the Titan IIIM Stage I engine design, particularly of the redesigned thrust chamber components. This section reports the actual test conditions to which the components were subjected.

Figure 32 illustrates the four operating targets of the peripheral test series, together with the actual subassembly operating points attained during each test. The open symbols show the 20 second adjustment tests conducted at nearly nominal propellant inlet conditions. These adjustment tests were followed by the full duration demonstration tests, shown as solid symbols. The latter tests were conducted at peripheral propellant inlet conditions, which partly explains the very noticeable shift in thrust and mixture ratio between the 20 and 200 second tests. The remainder of the shift in some tests was the result of a thrust or mixture ratio control readjustment between the 20-second and the 200-second tests. In interpreting Figure 32, (all but two cases) the adjustment tests were odd numbered and the next successive even numbered test was the full duration test having the same target. The two exceptions were adjustment Test No. -208 and full duration Test No. -215, and adjustment Test No. -308 and full duration Test No. -310 (Test No. -309 was the test with an aborted start and is omitted).

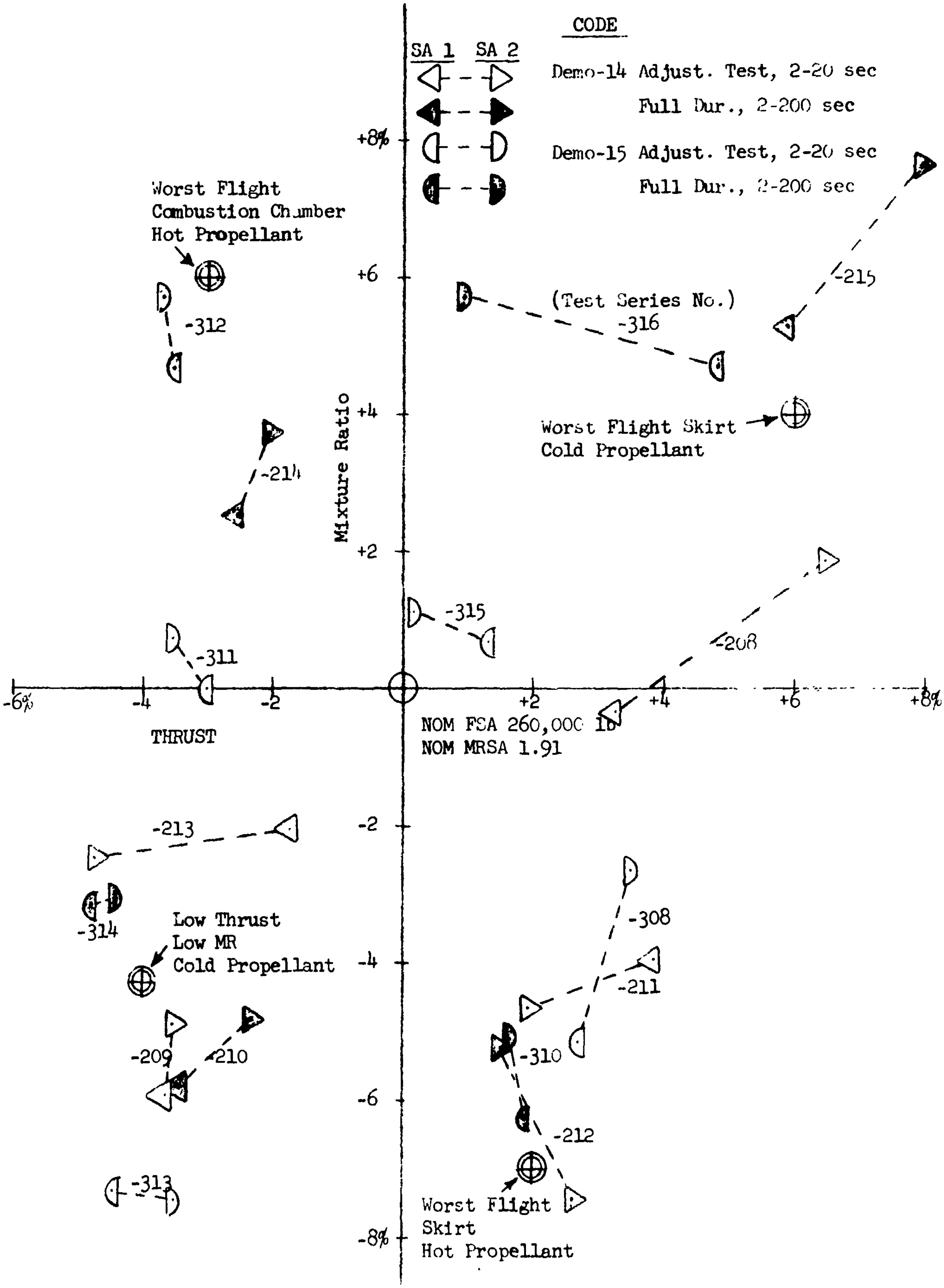


Figure 32 -- Actual Thrust and Mixture Ratio Peripheral Tests

Table 17 -- Peripheral Demonstration Tests -- Engine
Actual Conditions

Test Plan No. / Test Series No.	9 / -215				11 / -212				
	High Thrust, High MR, Cold Propellant (Worst Flight Skirt)				High Thrust, Low MR, Hot Propellant (Worst Flight Skirt)				Low Thr Propellant
Description	Target	SA 1	SA 2	Engine	Target	SA 1	SA 2	Engine	Target
POST, psia	110	112.9	113.7		67	74.1	72.7		110
PFST, psia	26	29.4	30.9		37	41.2	43.5		26
TOS, °F	35-40	41.4	41.4		85-90	90.3	90.5		85-90
TFS, °F	35-40	36.1	36.1		85-90	87.9	87.9		85-90
Thrust, lb x 10^{-3}	270.4	275.2	280.7	555.9	265.2	266.8	264.0	530.8	252.2
% from nom.	+4%	+5.8%	+8.0%	+6.9%	+2%	+2.6%	+1.5%	+ 2.1%	-3%
Mixture Ratio	2.025	2.011	2.056	2.038	1.776	1.768	1.810	1.789	2.025
% from nom.	+6%	+5.3%	+7.6%	+6.5%	-7%	-7.4%	-5.2%	-6.3%	+6%
Thrust Chamber Heat Flux Ratio (RBO)[(1)]		0.650	0.656			0.578	0.696		

(1) Design RBC for Titan IIIM, Stage I, is 0.82 maximum.

Peripheral Demonstration Tests -- Engine S/N 14,
Actual Conditions

11 / -212				13 / -214				15 / -210			
High Thrust, Low MR, Hot pellant (Worst Flight Skirt)				Low Thrust, High MR, Hot Propellant (Worst Comb. Chamber)				Low Thrust, Low MR, Cold Propellant			
get	SA 1	SA 2	Engine	Target	SA 1	SA 2	Engine	Target	SA 1	SA 2	Engine
	74.1	72.7		110	111.7	109.6		82	87.5	85.2	
	41.2	43.5		26	31.4	32.4		32	36.7	37.7	
90	90.3	90.5		85-90	90.2	90.1		35-90	39.8	40.2	
90	87.9	87.9		85-90	89.3	89.0		35-90	38.0	38.0	
.2	266.8	264.0	530.8	252.2	253.4	254.7	508.1	249.6	251.1	253.9	505.0
	+2.6%	+1.5%	+2.1%	-3%	-2.5%	-2.0%	-2.3%	-4%	-3.4%	-2.4%	-2.9%
76	1.768	1.810	1.789	2.025	1.958	1.981	1.970	1.828	1.799	1.817	1.808
	-7.4%	-5.2%	-6.3%	+6%	+2.5%	+3.7%	+3.1%	-4.3%	-5.8%	-4.9%	-5.4%
	0.578	0.696			0.730	0.736			0.641	0.663	

2

Table 18 -- Peripheral Demonstration Tests -- Engine S/N 1
Actual Condition

Test Plan No. / Test Series No.	9 / -316				11 / -310				
Description	High Thrust, High MR, Cold Propellant (Worst Flight Skirt)				High Thrust, Low MR, Hot Propellant (Worst Flight Skirt)				Lo Propel
	Target	SA 1	SA 2	Engine	Target	SA 1	SA 2	Engine	Targe
POST, psia	110	108.2	114.6		67	71.7	75.9		110
PFST, psia	26	29.9	34.0		37	41.1	43.3		26
TOS, ^{o}F	35-40	38.4	38.2		85-90	89.6	89.4		85-90
TFS, ^{o}F	35-40	37.0	36.9		85-90	88.6	88.8		85-90
Thrust, lb x 10^{-3}	270.4	272.5	262.5[2]	535.0	265.2	264.8	264.2	529.0	252.2
% from nom.	+4%	+4.8%	+1.0%	+2.9%	+2%	+1.8%	+1.6%	+1.7%	-3%
Mixture Ratio	2.025	2.000	2.019	2.009	1.776	1.791	1.811	1.801	2.025
% from nom.	+6%	+4.7%	+5.7%	+5.2%	-7%	-6.3%	-5.2%	-5.7%	+6%
Thrust Chamber Heat Flux Ratio (RBO)[1]		0.660	0.672			0.687	0.693		

(1) Design RBO for Titan IIIM, Stage I, is 0.82 maximum.

(2) Thrust was low on subassembly 2, test 316, as a result of a special test objective to suppress cavitation of the gas generator fuel venturi.

n Tests -- Engine S/N 15,

1 / 10		13 / -312				15 / -314			
Low MR, Hot t Flight Skirt)		Low Thrust, High MR, Hot Propellant (Worst Comb. Chamber)				Low Thrust, Low MR, Cold Propellant			
SA 2	Engine	Target	SA 1	SA 2	Engine	Target	SA 1	SA 2	Engine
75.9		110	113.8	116.3		82	85.7	88.3	
43.3		26	29.9	32.0		32	31.4	33.4	
89.4		85-90	90.0	89.6		35-90	41.1	40.9	
88.8		85-90	90.6	90.2		35-90	37.4	37.3	
264.2	529.0	252.2	250.8	250.5	501.2	249.6	247.5	248.5	496.0
+1.6%	+1.7%	-3%	-3.5%	-3.7%	-3.6%	-4%	-4.8%	-4.4%	-4.6%
1.811	1.801	2.025	1.999	2.020	2.009	1.828	1.849	1.851	1.850
-5.2%	-5.7%	+6%	+4.7%	+5.8%	+5.2%	-4.3%	-3.2%	-3.1%	-3.1%
0.693			0.744	0.749			0.635	0.639	

2

3.1, Engine Performance (cont.)

The peripheral propellant inlet conditions applied only during the full duration tests. The average conditions during these tests are shown in Tables 17 and 18 for engines S/N 14 and S/N 15, respectively. Shown are target and actual conditions of inlet pressure and temperature, subassembly and engine thrust and mixture ratio, as well as the calculated burnout heat flux ratio (RBO) for the thrust chamber.

Thrust Chamber Heat Flux Ratio

The peripheral tests demonstrated the cooling capability of the combustion chamber under simulated "worst flight" conditions. Table 19 shows the heat flux ratio (RBO) calculated for all of the Demonstration tests, arranged by Test Plan No. (rather than Test Series No.) in order to group together the equivalent peripheral tests. The main test objective of Test Plan No. 13 was to demonstrate the combustion chamber cooling tube design, and therefore was conducted with test conditions designed to attain the most severe heat flux conditions that might be expected during flight. These conditions were low thrust, high mixture ratio, and high propellant temperatures. They resulted in a calculated thrust chamber RBO of 0.730* and 0.736# for engine S/N 14 and 0.744* and 0.749# for engine S/N 15, compared to the design specification maximum RBO of 0.82. The values in Table 19 were calculated using the current empirical thrust chamber curves of RBO vs MRTC, Tci and P_c, and assuming a design fuel film cooling of 10.5 percent. Demonstration test data from the 19 to 21-second time interval were selected, as this period yielded maximum ratios for most of the tests.

*Subassembly 1
#Subassembly 2

Table 19 -- Thrust Chamber Heat Flux Ratio

Demo Test Plan No.	Engine S/N 14 Test Series No.	Engine S/N 14 Heat Flux Ratio (RBO) SA 1	Engine S/N 14 Heat Flux Ratio (RBO) SA 2	Engine S/N 15 Test Series No.	Engine S/N 15 Heat Flux Ratio (RBO) SA 1	Engine S/N 15 Heat Flux Ratio (RBO) SA 2
1	-201	0.695	0.705	-301	0.683	0.702
2	-202	0.685	0.700	-302	0.680	0.679
3	-204	0.695	0.674	-305	0.667	0.676
4	-203	0.678	0.682	-303	0.677	0.678
5	-205	0.695	0.695	-304	0.678	0.678
6	-206	0.690	0.695	-306	0.671	0.672
7	-207	0.695	0.715	-307	0.673	0.695
8	-208	0.670	0.688	-315	0.689	0.702
9	-215	0.650	0.656	-316	0.660	0.672
10	-211	0.534	0.657	-308	0.655	0.668
11	-212	0.578	0.696	-310	0.687	0.693
12	-213	0.682	0.694	-311	0.690	0.708
13*	-214	0.730	0.736	-312	0.744	0.749
14	-209	0.632	0.644	-313	0.633	0.636
15	-210	0.641	0.663	-314	0.635	0.639

*Worst flight combustion chamber test
(low thrust, high MR, high propellant temperature)

Data time period: 19 to 21 sec

Titan IIIM, Stage I, Design RBO: 0.82 max.

Table 20 -- Start Transient Requirements and Test Res

TRANSIENT CONDITIONS	CEI LIMITS			Test Plan No. / Test 3051-D07-1A / Type of Start System	1 / -301 / N_2	2 / -302 / SC	4 / -303 / SC	5 / -304 / SC	3 / -305 / SC	6 / -306 / SC	7 / -307 / SC
1. Propellant Consumption Between FS1 and 90% Rated Thrust	(Fuel) 760 lb	(Max)		Eng	280.8	289.3	271.0	283.5	288.0	279.7	282.9
	(Oxid) 1,460 lb	(Max)		Eng	529.4	524.7	485.1	509.7	510.6	502.0	504.2
2. Thrust Overshoot	323,000 lb	(Max)		SA-1	260,066	263,657	265,978	--	--	261,162	--
				SA-2	--	260,511	262,230	262,816	262,866	--	--
3. Dwell Time Over 103% Rated Thrust	.500 sec	(Max)		SA-1	--	--	--	--	--	--	--
				SA-2	--	--	--	--	--	--	--
4. Thrust Buildup Pate, 0 to 60% Rated F	23,000 lb/msec	(Max)		SA-1	7,702	12,651	15,689	14,414	15,204	12,839	11,728
				SA-2	10,014	10,181	10,726	9,197	16,512	11,451	10,944
5. Thrust Buildup Rate, 60 to 100% Rated F	1,700 lb/msec	(Max)		SA-1	735	1,002	1,015	938	853	1,108	1,056
				SA-2	733	1,006	1,011	[illegible]40	929	873	966
6. Spike Extension of Initial Buildup of Rated Thrust	75% of Rated F	(Max)		SA-1	58.8	70.8	78.1	81.7	77.1	70.2	72.4
				SA-2	62.9	70.0	71.1	73.3	73.2	71.5	69.4
7. Initial Buildup Spike at or Above 60% of Rated Thrust	.020 sec	(Max)		SA-1	--	.016	.020	.018	.018	.011	.021
				SA-2	.006	.008	.016	.025	.020	.010	.017
8. Thrust Buildup											
a. Time, FS1 to Initial P_c	.6 to 1.2 sec			SA-1	.899	.748	.704	.717	.710	.721	.734
				SA-2	.902	.794	.750	.714	.716	.750	.735
b. Thrust Buildup Time to 15% Rated F (from Initial P_c)	.010 sec	(Min)		SA-1	.030	.034	.030	.036	.032	.039	.030
				SA-2	.028	.031	.035	.028	.028	.040	.030
c. Thrust Buildup Time to 60% Rated F (from Initial P_c)	.025 to .500 sec			SA-1	.182	.145	.043	.049	.044	.107	.044
				SA-2	.173	.166	.048	.043	.041	.158	.047
d. Thrust Buildup Time to 80% Rated F (from Initial P_c)	.080 to .850 sec			SA-1	.270	.217	.195	.223	.219	.207	.209
				SA-2	.261	.240	.229	.223	.234	.246	.232
e. Thrust Buildup Time to 90% Rated F (from Initial P_c)	.100 to 1.10 sec			SA-1	.341	.317	.255	.290	.292	.289	.301
				SA-2	.310	.313	.290	.298	.300	.313	.311
f. Thrust Buildup Time to 97% Rated F (from Initial P_c)	10.000 sec	(Max)		SA-1	.983	.384	.358	.350	.368	.340	.365
				SA-2	.348	.415	.353	.385	.368	.396	.387
g. Differential Time of Initial P_c Rise Between SA 1 & SA 2	.200 sec	(Max)		Eng	.003	.046	.045	.003	.006	.029	.001
9. Differential Impulse Between SA 1 & SA 2 During 90 to 97% Rise Period	45,600 lb-sec	(Max)		Eng	1,270	1,187	949	248	311	1,038	6,754

(1) Subassembly 1 on Test -309 failed to start. Transient data is invalid.
(2) Tests -312, -313, and -314 were low thrust peripheral tests, and did not reach 97% of rated thrust. This condition was predeclared.

1

art Transient Requirements and Test Results

2 -302 SC	4 -303 SC	5 -304 SC	3 -305 SC	6 -306 SC	7 -307 SC	10 -308 N_2	11a -309 SC (1)	11b -310 SC	12 -311 N_2	13 -312 SC	14 -313 N_2	15 -314 SC	8 -315 N_2	9 -316 SC
89.3	271.0	283.5	288.0	279.7	282.9	276.6	--	295.2	279.7	297.1	300.3	354.5	307.5	310.5
24.7	485.1	509.7	510.6	502.0	504.2	496.8	--	481.9	387.6	599.3	519.6	611.7	562.3	605.9
63,657	265,978	--	--	261,162	--	251,552	--	261,169	--	--	--	--	--	260,473
60,511	262,230	262,816	262,866	--	--	279,009	--	260,318	274,079	--	266,028	--	261,387	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	.170	--	--	.085	--	--	--	--	--
2,651	15,689	14,414	15,204	12,839	11,728	7,149	--	10,471	7,328	10,924	7,420	14,120	7,110	10,587
0,181	10,726	9,197	16,512	11,451	10,944	9,700	13,620	9,342	9,207	8,049	9,518	12,135	9,511	14,249
,002	1,015	938	853	1,108	1,056	781	--	1,029	802	763	780	670	641	464
,006	1,011	940	929	873	966	800	877	983	737	834	823	664	840	513
0.8	78.1	81.7	77.1	70.2	72.4	57.5	--	66.3	64.7	68.5	56.9	68.2	58.0	76.2
0.0	71.1	73.3	73.2	71.5	69.4	61.9	59.2	61.3	63.5	70.2	62.2	74.5	62.8	79.5
016	.020	.018	.018	.011	.021	--	--	.010	.007	.013	--	.011	--	.021
008	.016	.025	.020	.010	.017	0	--	0	.010	.001	.001	.014	.001	.016
748	.704	.717	.710	.721	.734	.896	--	.742	.877	.769	.880	.718	.930	.721
794	.750	.714	.716	.750	.735	.904	.763	.774	.877	.761	.896	.710	.885	.720
034	.030	.036	.032	.039	.030	.036	--	.029	.042	.031	.041	.030	.044	.028
031	.035	.028	.028	.040	.030	.042	.038	.037	.043	.036	.039	.032	.042	.035
145	.043	.049	.044	.107	.044	.203	--	.119	.205	.157	.228	.044	.232	.043
166	.048	.043	.041	.158	.047	.199	.052	.167	.196	.155	.209	.046	.176	.049
217	.195	.223	.219	.207	.209	.279	--	.206	.283	.242	.310	.275	.351	.293
240	.229	.223	.234	.246	.232	.268	.235	.252	.278	.243	.286	.273	.252	.272
317	.255	.290	.292	.289	.301	.326	--	.311	.344	.368	.399	.420	.442	.372
313	.290	.298	.300	.313	.311	.308	.332	.341	.324	.385	.337	.418	.311	.379
384	.358	.350	.368	.340	.365	.451	--	.556	5.167	(2)	(2)	(2)	.951	.463
415	.353	.385	.368	.396	.387	.342	.436	.485	.357	(2)	.377	(2)	.361	.601
046	.046	.003	.006	.029	.001	.008	--	.032	0.0	.008	.016	.008	.055	.001
,187	949	248	311	1,038	6,754	505	--	716	552	1,427	702	1,468	3,821	1,237

is invalid.
, and did not reach 97% of rated thrust.

2

Table 20 -- Start Transient Requirements and Test Resul

TRANSIENT CONDITIONS	CEI LIMITS			Test Plan No. Test 3051 D07-1A Type of Start System: 1 -201 N_2	2 202 SC	4 -203 SC	3 -204 SC	5 -205 N_2	6 -206 SC
1. Propellant Consumption Between FS1 and 90% of Rated Engine Thrust	(Fuel) 760 lb (Oxid) 1,460 lb	(Max) (Max)	Eng Eng	268.6 509.3	265.4 498.5	265.0 492.2	262.1 476.2	272.4 508.6	290.5 540.6
2. Thrust Overshoot	323,000 lb	(Max)	SA-1 SA-2	269,464 285,504	263,984 249,765	262,542 250,652	261,963 260,214	273,001 285,686	260,825 --
3. Dwell Time Over 103% Rated Thrust	0.500 sec	(Max)	SA-1 SA-2	.054 .177	0 0	0 0	0 0	.071 .192	0 0
4. Thrust Buildup Rate, 0 to 60% Rated F	23,000 lb/msec	(Max)	SA-1 SA-2	7,686 7,340	12,139 12,682	9,913 9,195	10,383 6,849	9,146 6,482	11,232 11,504
5. 60 to 100% Rated F	1,700 lb/msec	(Max)	SA-1 SA-2	777 801	1,058 1,053	1,113 1,137	1,168 1,046	781 765	1,059 1,083
6. Spike Extension of Initial Buildup in Percent of Rated Thrust	75% F	(Max)	SA-1 SA-2	57.7 52.7	68.8 69.4	68.5 63.8	70.0 73.6	55.1 55.7	67.0 69.5
7. Initial Buildup Spike Duration at or Above 60% of Rated Thrust	.020 sec	(Max)	SA-1 SA-2	0 0	.010 .007	.013 .010	.012 .013	0 0	.012 .010
8. Thrust Buildup									
8. Time, FS1 to Initial Pc	0.6 to 1.2 sec		SA-1 SA-2	.921 .928	.773 .761	.760 .747	.727 .743	.890 .901	.754 .750
9. Thrust Buildup Time to 15% Rated F (From Initial Pc)	.010 sec	(Min)	SA-1 SA-2	.040 .029	.028 .030	.032 .020	.036 .032	.040 .028	.039 .031
10. Thrust Buildup Time to 60% Rated F (From Initial Pc)	.025 to .500 sec		SA-1 SA-2	.198 .185	.148 .158	.151 .113	.148 .140	.189 .180	.054 .147
11. Thrust Buildup Time to 80% Rated F	.080 to .850 sec		SA-1 SA-2	.275 .260	.204 .218	.205 .194	.198 .200	.269 .262	.220 .238
12. Thrust Buildup Time to 90% Rated F	.100 to 1.100 sec		SA-1 SA-2	.322 .302	.250 .299	.246 .288	.232 .255	.312 .304	.315 .330
13. Thrust Buildup Time to 97% Rated F	10.000 sec	(Max)	SA-1 SA-2	.359 .342	.313 .436	.329 .407	.26[illegible] .367	.351 .338	.408 .422
14. Differential Time of Initial Pc Rise Between SA 1 and SA 2	.200 sec	(Max)	Eng	.007	.012	.013	.016	.011	.005
15. Differential Impulse Between SA 1 & SA 2 During 90 to 97% Rise Period	45,600 lb-sec	(Max)	Eng	[illegible]60	875	303	877	24	363

(1) Tests -209, -210, 213, and 214 were low thrust peripheral tests, and did not reach 97% of rated thrust.

ments and Test Results (cont.)

3	5	6	7	8	14	15	10	11	12	13	9
204	-205	-206	-207	-208	-209	-210	-211	-212	-213	-214	-215
SC	N_2	SC	SC	N_2	N_2	SC	N_2	SC	N_2	SC	SC
2.1	272.4	290.5	287.2	274.2	323.4	324.1	283.4	29[illegible].3	308.4	297.1	272.1
76.2	508.6	540.6	522.1	512.9	580.5	605.1	507.5	493.9	551.2	550.5	563.7
1,963	273,001	260,825	262,857	260,409	--	--	268,338	261,891	--	--	--
0,214	285,686	--	261,092	--	--	--	260,019	260,372	--	--	--
	.071	0	0	0	0	0	.011	0	0	0	0
	.192	0	0	0	0	0	0	0	0	0	0
,383	9,146	11,232	11,551	6,667	7,624	14,662	8,556	17.367	10,906	10,015	11.942
,849	6,482	11,504	13,552	7,044	9,467	10,602	8,700	12,147	9,781	6,936	13.005
,168	781	1,059	1,026	756	722	692	865	726	703	773	1,042
,046	765	1,083	826	733	752	574	832	730	489	594	876
.0	55.1	67.0	66.0	55.1	57.9	71.5	56.9	74.0	57.7	65.2	75.2
3.6	55.7	69.5	72.0	53.4	59.4	73.4	54.8	70.5	58.5	70.5	71.8
012	0	.012	.013	0	0	.011	0	.020	0	.007	.020
013	0	.010	.014	0	0	.009	0	.010	0	.000	.015
727	.890	.754	.748	.910	.880	.754	.873	.685	.882	.745	.736
743	.901	.750	.781	.931	.915	.738	.897	.681	.914	.745	.746
036	.040	.039	.030	.044	.044	.036	.047	.041	.044	.036	.041
032	.028	.031	.034	.045	.034	.042	.039	.035	.040	.030	.034
148	.189	.054	.119	.197	.218	.049	.178	.052	.191	.129	.056
140	.180	.147	.049	.195	.200	.056	.196	.052	.221	.057	.051
198	.269	.220	.202	.280	.299	.304	.248	.276	.260	.227	.195
200	.262	.238	.2[illegible]2	.272	.283	.304	.271	.238	.306	.265	.209
232	.312	.315	.298	.341	.397	.411	.315	.343	.323	.317	.303
255	.304	.330	.318	.315	.400	.401	.340	.329	.429	.347	.290
264	.351	.408	.384	.433	(1)	(1)	.362	.447	.468	(1)	.376
367	.338	.422	.398	.368	(1)	(1)	.404	.421	(1)	3.400	.395
.016	.011	.005	.033	.021	.035	.016	.024	.004	.032	0.000	0.010
77	24	363	1,003	376	[illegible],853	16,666	1,334	425	12,801	1.331	538

ch 97% of rated thrust. This condition was predeclared.

2

3.1, Engine Performance (cont.)

3.1.3 Transient Operation

Start Transients

The CEI Specification start transient requirements and the corresponding Demonstration test results are shown in Table 20. The only parameters that were outside the specification limits were the magnitude and the duration of the initial thrust buildup "spikes" on engine S/N 15 (refer to lines 6 and 7 in Table 20b). This anomaly occurred during Tests Nos. -303, -304, -305, -307, and -316. In each case, the cause was determined to be the pretest environment of the start cartridge, which allowed the cartridge temperature to approach or exceed the allowable limit (established by the batch test of the sister cartridge). Prior to each of the tests cited above, the cartridges were conditioned between 70 and 78°F (nominal is 60°F) and then were exposed on the engine, without conditioning, for 3 to 11 hours prior to actual firing time at ambient temperatures ranging from 74° to 102°F. Table 21 presents applicable start cartridge data for engines S/N 14 and S/N 15, respectively.

Start transient data for the gaseous nitrogen start tests are included in Table 20 for reference only. The data differ from the solid cartridge test data and are not applicable to the specification requirements.

Shutdown Transients

The CEI Specification shutdown transient requirements and the corresponding Demonstration test results are shown in Table 22. None of the parameters fell outside the limits except during certain excluded tests as noted in the table.

Table 21 -- Start Cartridge Flow Rates and Environmental Data

Test No.	S/A	SSC S/N	Flow Rate, W_B: Batch, lb/sec	Flow Rate, W_B: Actual, lb/sec	Case Temperature, °F: Allowable Range, °F	Case Temperature, °F: Estimated Actual, °F	Conditioning Box Temperature, °F	Ambient Temp, °F Date	Time Out of Conditioning Box, hours
Demo Engine S/N 14									
-202	1	4116	5.20	4.60	25-71		65		2
	2	4156	4.91	4.56	35-82			12/29/67	
-203	1	859656	4.95	4.70	35-81		69		2
	2	859660	5.12	4.67	28-74			1/10/68	
-204	1	4153	5.00	4.69	32-79		70		1.8
	2	859613	4.99	4.85	33-79			3/11/68	
-206	1	4106	4.97	4.88	34-80		70		3.6
	2	4137	4.96	4.95	34-81			4/10/68	
-207	1	859649	4.90	4.92	37-83		60		4
	2	859659	4.91	5.04	35-82			4/29/68	
-210	1	859661	4.70	5.42	45-91	90	79	105-101	3.8
	2	859671	4.68	5.40	46-92			7/5/68	
-212	1	5407	4.52	6.25	52-98	95	98	91-88	4.5
	2	5408	4.48	5.45	54-100			7/12/68	
-214	1	4105	4.65	5.39	47-93	85	70	87-98	2.9
	2	5334	4.65	5.40	47-93			7/22/68	
-215	1	2508	4.80	5.29	41-87	73	68	75-82	2.6
	2	4142	4.81	5.20	41-86			8/27/68	

Table 21 -- Start Cartridge Flow Rates and Environmental Data (cont.)

Test No.	S/A	SSC S/N	Flow Rate, W_B Batch, lb/sec	Flow Rate, W_B Actual, lb/sec	Case Temperature, °F Allowable Range, °F	Case Temperature, °F Estimated Actual, °F	Conditioning Box Temperature, °F	Ambient Temp, °F Date	Time Out of Conditioning Box, hours
Demo Engine S/N 15									
-302	1	4144	4.86	4.75	38-84	70	70	67-70	2.2
	2	860648	4.87	4.70	38-84			6/6/68	
-303	1	4090	4.90	4.95	35-81	70	60-72	89-70	
	2	859653	4.92	4.80	35-82			6/14/68	
-304	1	4108	4.75	5.38	43-89	90	78-71	92-97	3.2
	2	4150	4.75	5.17	43-89			6/18/68	
-305	1	5333	4.71	5.35	45-90	85	70	76-89	11.3
	2	859650	4.71		45-90			6/24/68	
-306	1	4147	4.66	4.86	47-92	80	70	70-89	3.4
	2	5335	4.65	4.88	47-93			7/26/68	
-307	1	4124	4.59	4.93	50-95	85	70	82-93	6.2
	2	4132	4.62	5.03	48-94			8/1/68	
-309	1	4133		5.25			70		2
	2	4135	4.79	5.22	41-87			8/15/68	
-310	1	2561	4.77	5.19	42-88	75	70	80-82	3
	2	4162	4.77	5.85	42-88			8/16/68	
-312	1	4161	4.57	4.91	50-96	70	70	76-77	0.8
	2	859609	4.56	4.68	51-96			9/19/68	
-314	1	5331	4.69	5.08	45-91	80	84	74-78	1.7
	2	5332	4.75	5.50	43-89			10/1/68	
-316	1	5405	5.09		29-75	70	72	52-74	7.5
	2	5415	5.01		32-79			10/17/68	

Table 22 -- Shut Down Transient

TRANSIENT CONDITIONS	CEI LIMITS		Test Plan No. / Test 3051-D07-1A	1 / -201	2 / -202	4 / -203	3 / -204
1. Thrust Decay Rate from Full to 10% of Rated Engine Thrust	2,500 lb/msec	(Max)	SA 1	1,085	1,111	1,524	972
			SA 2	1,157	1,515	1,191	(1)
2. Thrust Decay Time from FS2 to 25% of Rated Engine Thrust	FS2+0.8 sec	(Max)	Eng	.464	.454	.462	(1)
3. Differential Shutdown Impulse Between SA 1 and SA 2	60,000 lb-sec	(Max)	Eng	3,150	3,139	3,181	(1)
4. Total Shutdown Impulse After FS2 to 3% of Rated Engine Thrust (2)	270,000 lb-sec	(Max)	Eng	208,138	204,279	206,503	(1)

(1) TPA failure on S/A 2; shutdown data invalid.
(2) Special post fire purge was required for test numbers -204, -206, -214, and -215 which were ablative skirt tests. Total shutdown impulse data for these tests are invalid.

TRANSIENT CONDITIONS	CEI LIMITS		Test Plan No. / Test 305ˀ D07-1A	1 / -301	2 / -302	4 / -303	5 / -304	3 / -3C
1. Thrust Decay Rate from Full to 10% of Rated Engine Thrust	2,500 lb/msec	(Max)	SA-1	1,081	1,064	1,138	1,163	1,02ˀ
			SA-1	1.103	1,182	1,225	1,204	915
2. Thrust Decay Time from FS2 to 25% of Rated Engine Thrust	FS2 + 0.8 sec	(Max)	Eng	.467	.452	.450	.450	.529
3. Differential Shutdown Impulse Between SA 1 and SA 2	60,000 lb-sec	(Max)	Eng	9,270	9,174	8,800	12,247	10,421
4. Total Shutdown Impulse After FS2 to 3% of Rated Engine Thrust	270,000 lb-sec	(Max)	Eng	210,980	209,463	207,983	210,122	(2)

(1) Subassembly 1 on Test -309 failed to start. Transient data are invalid.
(2) Special post fire purge was required for test numbers -305, -307, and -316 which were ablative skirt tests. Total shutdown impulse data for these tests are invalid.

Table 22 -- Requirements and Test Results

5 -205	6 -206	7 -207	8 -208	14 -209	15 -210	10 -211	11 -212	12 -213	13 -214	9 -215
1,203 1,161	973 1,086	1,110 1,194	1,112 1,282	1,183 1,113	1,639 1,270	1,768 1,247	1,242 1,159	1,095 1,172	1,025 1,001	975 1,110
.468	.479	.454	.469	.451	.448	.474	.430	.455	.505	.520
1,515	1,856	4,762	8,467	4,419	5,171	3,525	7,581	-2,167	3,327	3,860
213,744	250,465	208,855	222,509	192,057	194,727	221,352	213,504	200,197	240,337	256,707

6 -306	7 -307	10 -308	11a -309 (1)	11b -310	12 -311	13 -312	14 -313	15 -314	8 -315	9 -316
1,141 1,292	1,037 990	1,089 1,270	-- 1,200	1,238 1,279	1,237 1,233	1,143 1,194	1,098 1,521	1,332 1,213	1,543 1,092	889 989
.448	.519	.457	--	.431	.452	.458	.461	.455	.453	.558
8,408	6,815	7,082	--	1,359	433	1,518	932	2,003	2,801	1,366
207,549	(2)	215,179	--	218,470	199,535	227,337	197,674	205,859	207,415	(2)

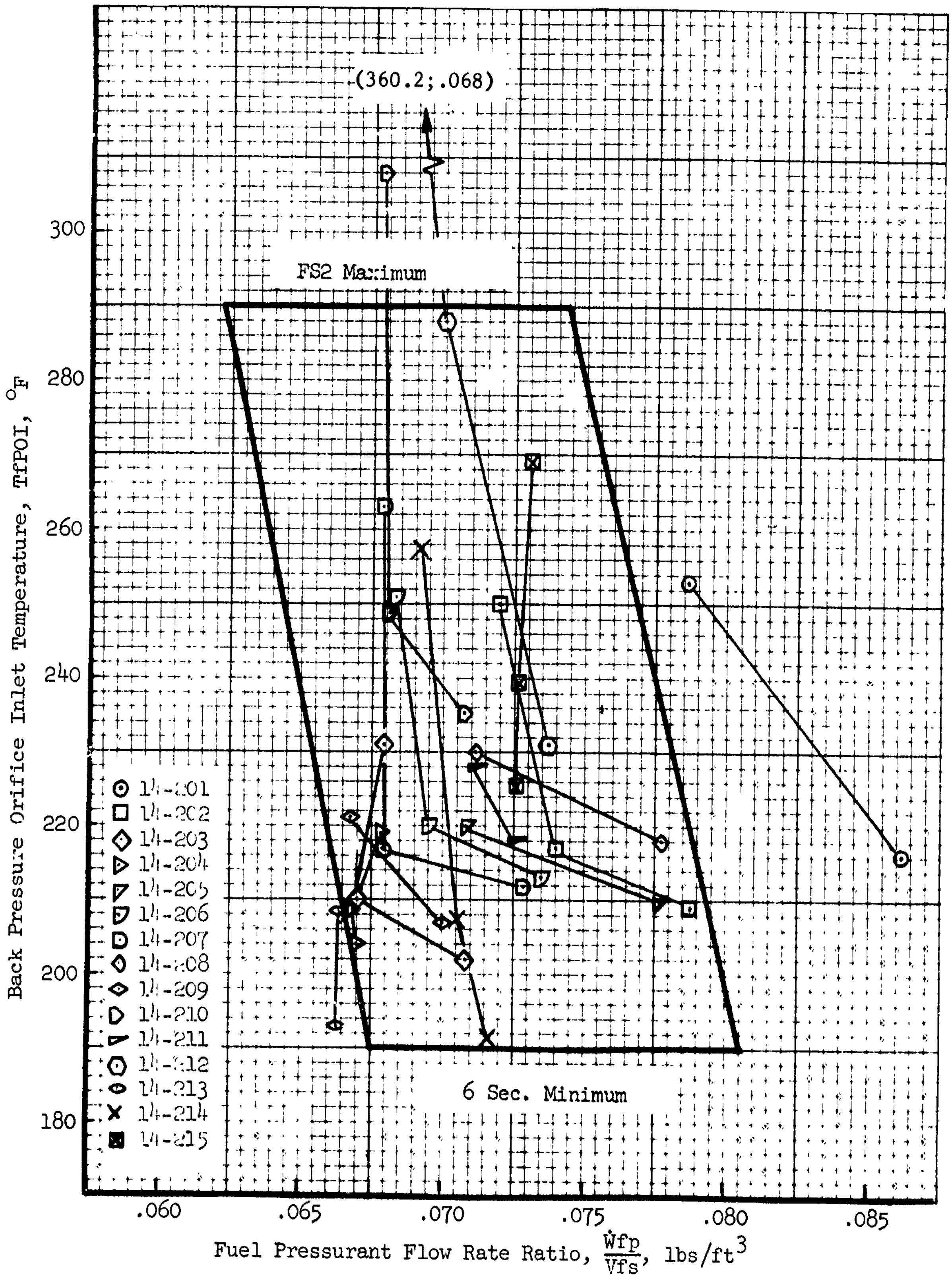


Figure 33 -- Fuel Autogenous Pressurization System Performance, Engine S/N 14

3.1, Engine Performance (cont.)

3.1.4 Autogenous Systems

Figures 33 and 34 show the fuel autogenous pressurization system performance for all the engine demonstration tests. In Figure 33, all the tests with engine S/N 14 were within the specification box limits with the following exceptions:

> Test No. -201 was outside the box because it was the initial engine adjustment test; a flow control adjustment brought the next test within the box.
>
> Tests No. -210 and No. -212 exceeded the FS2 maximum temperature limit (T_{fp0i}), because during these tests only, a restriction was inadvertently included in the fuel coolant line in conjunction with the installation of the POGO suction line. This suction line was fabricated with a 3/8-in. boss (normally 1/2-in.) for the fuel coolant return connection. T_{fp0i} was higher during Test No. -212 than during Test No. -210 because the engine propellant inlet temperature was higher, 90°F vs 35°F. During the Test No. -215, the next test with POGO accumulators, the suction line included the correct size of boss, fuel coolant flow resistance decreased, flow increased, and T_{fp0i} decreased to normal.
>
> The data from Test No. -213 were outside the minimum flow limit because of the low thrust, peripheral test conditions. On the succeeding test, thrust was increased nearer to rated thrust and the autogenous flow also increased to within specification limits.

In Figure 34 the data from the performance evaluation with engine S/N 15, Test Nos. -302 through -306, were within the box limits. The data from some of the peripheral tests were outside the limits, and show a larger scatter when compared to the engine S/N 14 tests (Figure 33), because the engine S/N 15 was tested under more severe peripheral conditions of thrust and mixture ratio.

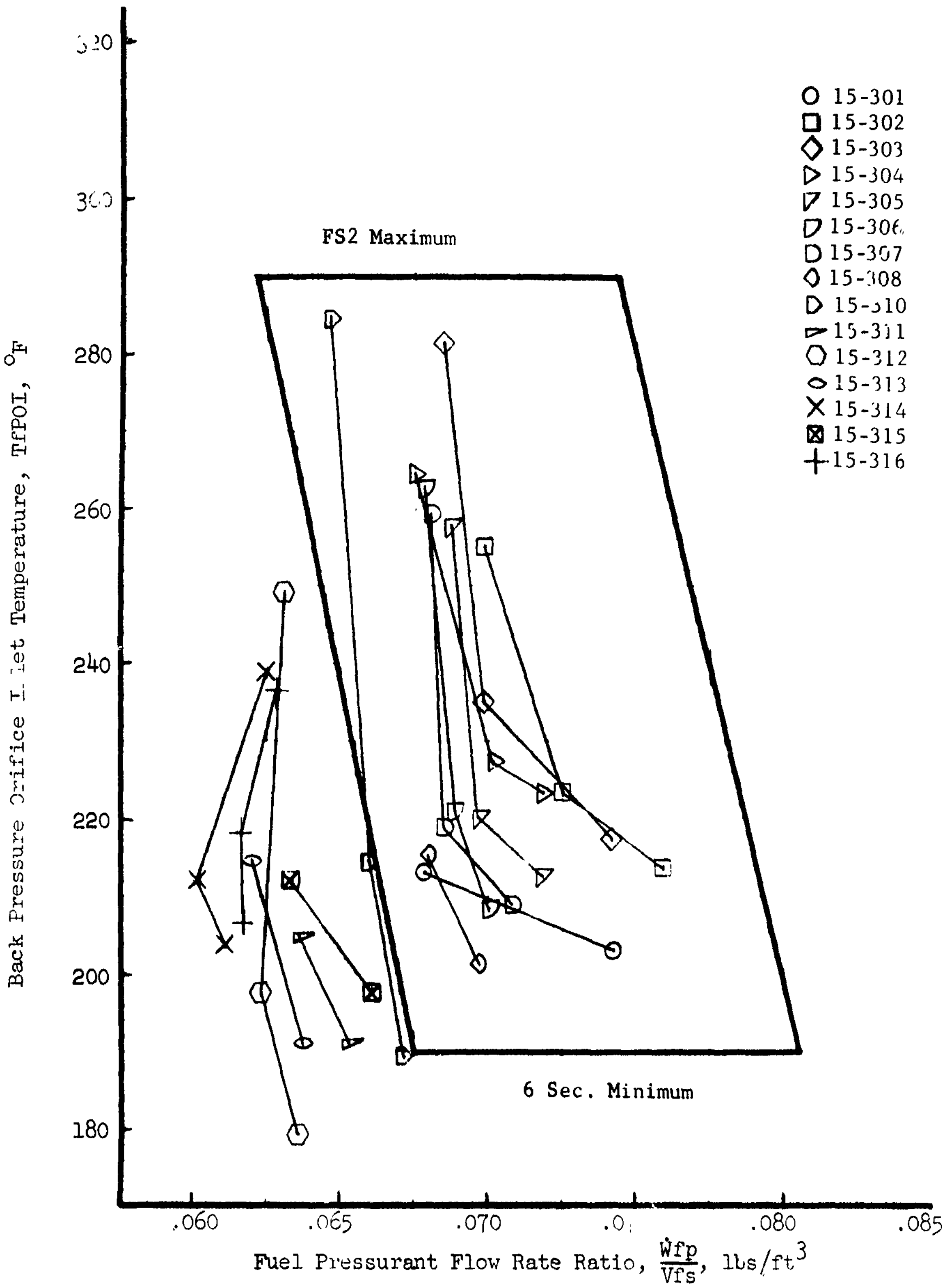


Figure 34 -- Fuel Autogenous Pressurization System Performance, Engine S/N 15

3.1, Engine Performance (cont.)

Of particular interest is the effect of 90° propellant inlet temperature, resulting in a larger increase in T_{fp0i} at the FS2 point. Test No. -310 in Figure 34 ranged the full distance between minimum and maximum box temperature limits.

Figures 35 and 36 show the oxidizer autogenous pressurization system performance for all the demonstration tests, with the exception of the special tests with increased autogenous flow which are described in Paragraph 3.1.5.

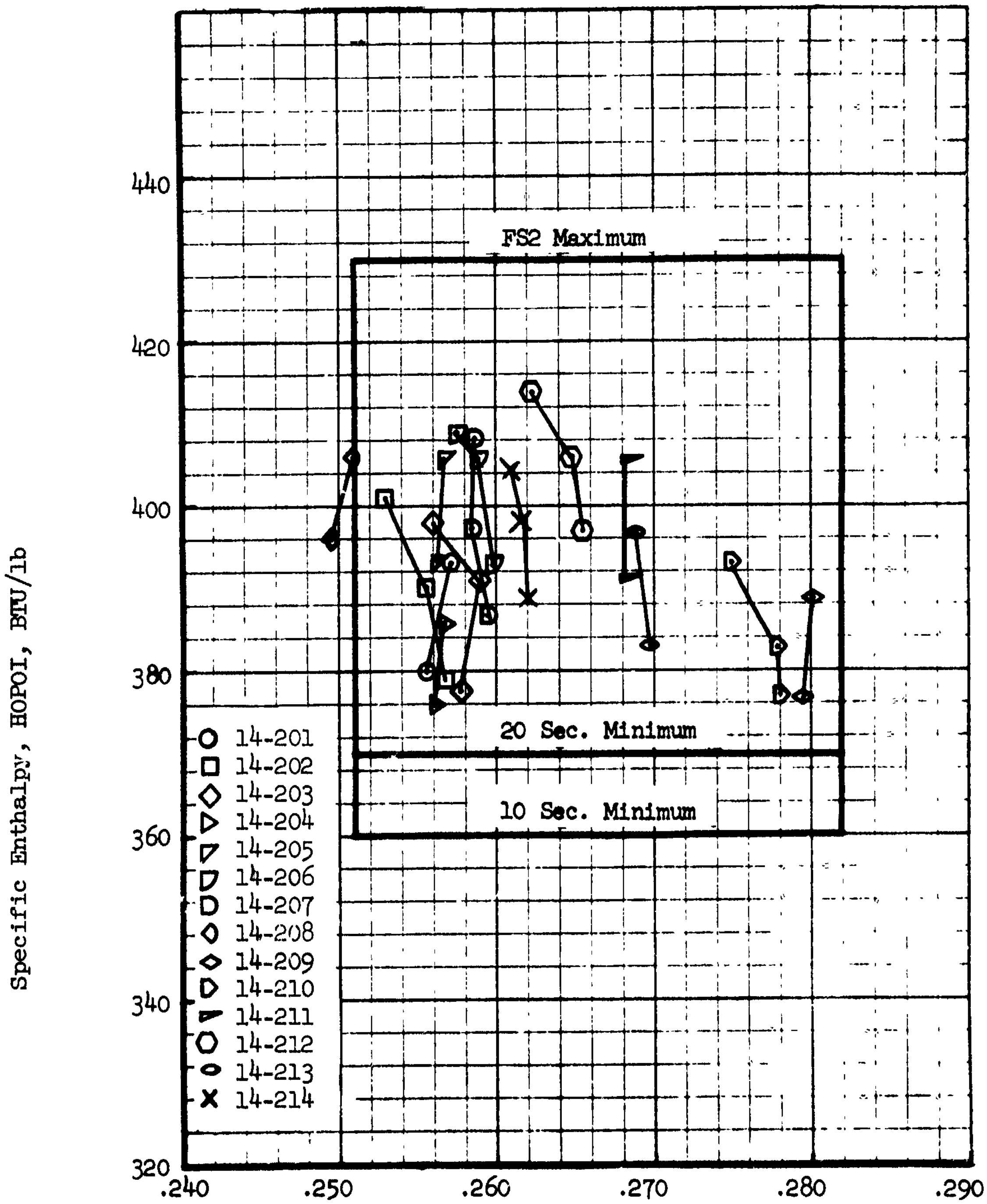
As shown in Figure 35, data from all the tests with engine S/N 14 fell within the box limits, with the exception of Test No. -208, which was a peripheral test with thrust and mixture ratio substantially outside specification limits.

Data from all applicable engine S/N 15 tests fell within the box limits, as shown in Figure 36. On Tests No. -306 and No. -307 the superheater bypass flow was blanked off preparatory to the special testing with increased oxidizer pressurant flow, but Tests No. -306 and No. -307 were still within the enthalpy limits of the box and are included in Figure 36.

3.1.5 Special Data Evaluations

Side Forces

Side forces on both engines were monitored during test firings. These forces, caused mainly by asymmetric flow separation, were determined by measuring the transient loading on the engine gimbal actuators or stiff links during sea level start conditions. The forces on the actuators were obtained from the differential pressures across them. The forces on the stiff links were obtained by means of strain gages; full strain gage bridges were mounted



Oxidizer Pressurant Flow Rate Ratio, $\frac{\dot{W}op}{Vos}$, lbs/ft^3

Figure 35 -- Oxidizer Autogenous Pressurization System Performance, Engine S/N 14

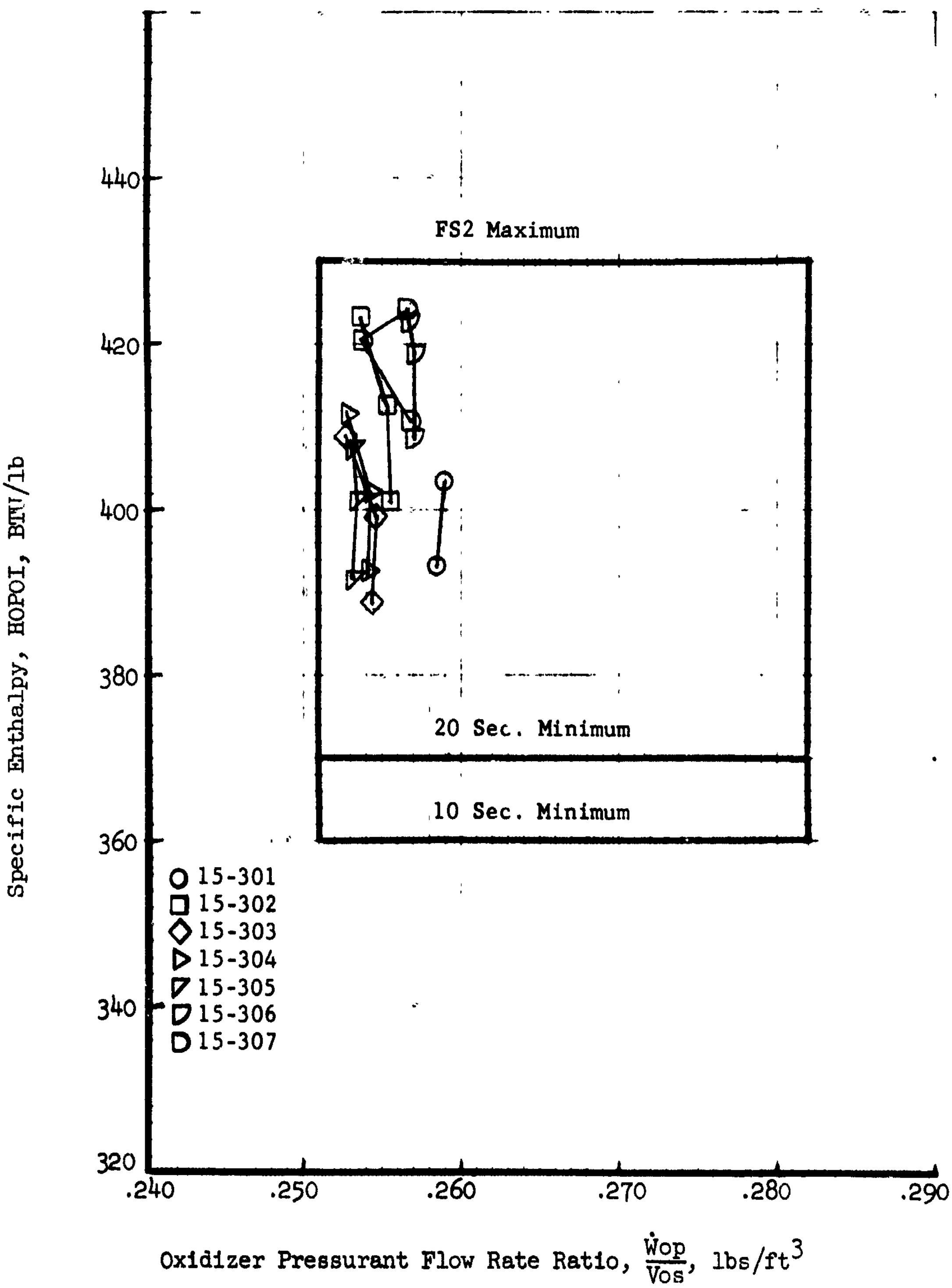


Figure 36 -- Oxidizer Autogenous Pressurization System Performance, Engine S/N 15

3.1, Engine Performance (cont.)

on the stiff links, and the links were then force calibrated by dead weight loading.

Individual gimbal actuator or stiff link forces were summed at a given instant for each case to produce the maximum vector resultant. The results have been separated into three groups: (1) 15:1 engine configuration with solid cartridge start, Table 23; (2) 6:1 engine configuration with solid cartridge start, Table 24, and (3) 6:1 engine configuration with gaseous nitrogen start, Table 25. Mean values, standard deviations, and sample sizes are also included for each group.

The objectives in monitoring side forces during these test firings were (1) to measure side loads in general for the various engine configurations, (2) to study side load phenomena, with emphasis on asymmetric flow separation, and (3) to verify analytically predicted side loads for the 15:1 engine configuration under sea level start conditions.

The 14 resultants listed in Table 23 were included in a 21-sample statistical analysis of side loads for the Titan IIIM Stage I engine with the 15:1 ablative skirt. The results of the analysis yielded a maximum actuator load of 68,560 lb for 0.999 probability at a 50% confidence level. This value is in excellent agreement with the analytically predicted value of 67,300 lb.

Combustion Dynamics

Combustion was stable throughout engine demonstration testing. With each engine operating within the limits described in Specification CP-40224, the units performed repeatedly with a broad-band noise character of 30 to 50 psi peak-to-peak amplitude. As shown in Figure 37, interpretation of the unfiltered data in respect to previous spectral analyses of the development

Table 23 -- Side Loads--Solid Cartridge Starts (15:1)

Run	Yaw (lb)	Pitch (lb)	Freq (cps)	Resultant (lb)	ϕ* (deg)
3051-D07-1A-204 (w/skirt)					
S/A 1	38K	0	9	38K	90
S/A 2	53K	33K	9	62.5K	58
3051-D07-1A-206 w/skirt					
S/A 1	30K	18K	9	50K	59
S/A 2	26K	26K	9	37K	45
3051-D07-1A-214 (w/skirt)					
S/A 1	20K	21K	12	29K	43
S/A 2	24K	14K	12	27.8K	30
3051-D07-1A-215 (w/skirt)					
S/A 1	40K	8K	10	40.8K	79
S/A 2	-20K	-13K	-	23.9K	237
3051-D07-1A-305 (w/skirt)					
S/A 1	30K	32.9K	10.1	44.5K	43
S/A 2	18.8K	-10.3K	10.1	21.5K	118
3051-D07-1A-307 (w/skirt)					
S/A 1	15K	27.3K	10	31.2K	28
S/A 2	16.2K	26.9K	10	33.1K	29
3051-D07-1A-316 (w/skirt)					
S/A 1	31.5K	11.3K	10	33.6K	70
S/A 2	28.2K	0	10	28.2K	90

Sample size = 14; Mean value = 35.79K; Standard deviation = 10.98K

*Angle ϕ measured clockwise looking aft; zero degrees at pitch actuator clevis.

Table 24 -- Side Loads--Solid Cartridge Starts (6:1)

RUN	SGYA (lb)	SGYB (lb)	FREQ (cps)	SGPA (lb)	SGPB (lb)	FREQ (cps)	RESULTANT (lb)	ϕ (deg)
3051-D07-1A-202								
Sub 1	14K	13.5K	-	24K	32K	25	32K	26
Sub 2	17K	15K	25	22K	20K	27	26.6K	37
3051-D07-1A-203								
Sub 1	26K	24K	25	22K	24K	29	34K	45
Sub 2	13K	12K	22	31K	30K	29	33.4K	23
3051-D07-1A-207								
Sub 1	15K	15K	22	-	19K	24	24.4K	38
Sub 2	22K	19K	22	19K	19K	24	28K	47
3051-D07-1A-210								
Sub 1	11.3K	9.9K	20	-	-	-	-	-
Sub 2	21K	18K	20	17K	16K	25	25.5K	50
3051-D07-1A-212								
Sub 1	16K	17K	22	30K	-	25	34K	29
Sub 2	18K	-	20	16K	16K	25	24K	42
3051-D07-1A-302								
Sub 1	15.3K	-	23	33.9K	33.8K	25	37.1K	24
Sub 2	-	-	-	-	-	-	-	-
3051-D07-1A-303								
Sub 1	15.3K	15K	23	31.7K	34.2K	25	36.4K	25
Sub 2	8K	9K	22	21.7K	-	25	23.3K	21

Table 24 -- Side Loads--Solid Cartridge Starts (6:1) (cont.)

RUN	SGYA (lb)	SGYB (lb)	FREQ (cps)	SGPA (lb)	SGPB (lb)	FREQ (cps)	RESULTANT (lb)	ϕ (deg)
3051-D07-1A-304								
Sub 1	10K	10K	23	35.8K	31.7K	25	35.1K	16
Sub 2	6.8K	13.6K	23	15.6K	-	-	-	-
3051-D07-1A-306								
Sub 1	37.5K	-	22	12K	-	22	39.4K	72
Sub 2	29.7K	-	20	20K	-	20	-	-
3051-D07-1A-310								
Sub 1	-	-	-	32K	32K	25	-	-
Sub 2	-	9K	-	16K	-	-	18.4K	29
3051-D07-1A-312								
Sub 1	-	-	-	31K	-	25	-	-
Sub 2	13.3K	-	23	23.8K	-	25	27.3K	29
3051-D07-1A-314								
Sub 1	9K	-	20	37.7K	-	22	38.8K	13
Sub 2	20K	-	20	34K	-	25	39.5K	30

Sample size = 18; Mean value = 30.95K; Standard deviation = 6.39K

Table 25 -- Side Loads--Gaseous Nitrogen Starts

RUN	SGYA (lb	SGYB (lb)	FREQ (cps)	SGPA (lb)	SGPA (lb)	FREQ (cps)	RESULTANT (lb)	ϕ (deg)
3051-D07-1A-201								
S/A 1	7K	6.5K	22	11K	10K	29	12.4K	33
S/A 2	16K	17K	25	9K	8.5K	29	18.8K	62
3051-D07-1A-205								
Sub 1	4.5K	4K	22	4K	5K	22	6.4K	45
Sub 2	7.5K	5.5K	25	-	-	-	-	-
3051-D07-1A-208								
Sub 1	9K	-	-	-	-	-	-	-
Sub 2	10K	10K	-	9K	9K	-	13.4K	48
3051-D07-1A-209								
Sub 1	7K	7K	22	19K	18K	23	20K	21
Sub 2	5K	-	20	14K	11.5K	24	13.7K	23
3051-D07-1A-211								
Sub 1	12K	14K	22	13K	17K	24	19.8K	41
Sub 2	5K	-	22	11K	11K	25	12K	24
3051-D07-1A-213								
Sub 1	11K	11K	22	-	-	-	-	-
Sub 2	6K	-	20	12K	13K	25	14K	26
3051-D07-1A-301								
Sub 1	8K	7.6K	20	17.7K	16.1K	25	18.6	25
Sub 2	-5.9K	-5.9K	23	-2.5K	-	27	6.4	247
3051-D07-1A-308								
Sub 1	6.2K	-	20	27.3K	27K	25	27.8	13
Sub 2	9K	7.5K	20	25K	25K	25	26.4	17
3051-D07-1A-313								
Sub 1	7K	-	-	31K	-	22	35K	13
Sub 2	14K	-	20	30K	-	26	33K	25
3051-D07-1A-315								
Sub 1	7K	-	20	-	-	-	-	-
Sub 2	11.8K	-	22	27.8	-	27	30.2K	23

Sample size - 16; Mean value = 19.24K; Standard deviation = 8.96K

Figure 37 -- Pressure Oscillations, P_c and P_{fj}

3.1, Engine Performance (cont.)

engine data indicated that a 1500 cps center-frequency was predominant for the broad band combustion noise. Occasionally, a clearly discernible 1500 cps signal appeared in the combustion pressure at amplitudes up to 70 psi peak-to-peak during the start and shutdown transients and sporadically during steady state. These signals were not reflected in the fuel manifolds, and during steady state they rarely lasted longer than 15 milliseconds in duration.

The 1500 cps oscillations noted above were experienced during the development testing of the engine. At no time during any of the testing did damage result from 1500 cps noise, even when the operation was carried out of the normal operating range and the amplitudes of the oscillation exceeded 100 psi.

Gas Cooler Accelerometers

Four accelerometers were mounted on hot gas cooler P/N 284889-19, S/N 753, prior to initiating demonstration testing with engine S/N 14. Accelerometer data were retrieved during the first four tests with engine S/N 14 prior to removing the accelerometer.

The accelerometers were installed on the Titan IIIM demonstration engine in an effort to establish the hot gas cooler vibration environment. Subsequent comparison with the previously established Titan III environment was also required.

Power spectral density plots from Titan III development Engine Test No. 1.2-06-SJA-008 were compared with plots obtained from engine S/N 14 testing. Data were plotted for three mutually perpendicular directions, X, Y, and Z. The Titan III test data had higher peaks and greater total energy up to 3000 Hz in all three axes than the Titan IIIM test data.

3.1, Engine Performance (cont.)

It should be noted that the Titan III test data were analyzed with a 64 Hz bandwidth filter and the Titan IIIM data with an 88 Hz bandwidth filter. The narrower filter tends to increase the amplitude of discrete frequencies in the data so no direct comparison of the peak values should be made.

Interface Panel Accelerometers

Accelerometers were installed on three axes on the redundant interface J-box mounting panel to measure the vibration environment of the redundant interface J-box. Vibration spectrum data from several engine runs were analyzed and a power spectral density plot made using the highest acceleration levels obtained. This plot is shown in Figure 38 and is actually an envelope of the several PSD plots obtained.

Knowledge of the vibration environment of the redundant interface J-box was desired since the J-box is a redesigned version of the existing Titan engine controls harness interface box. Redesign was necessary to meet the circuit isolation requirements of SSD-CR-65-8180-150, Electromagnetic Compatibility (EMC) Control Plan, and to add transient suppression diodes across the pressure sequence valve override solenoid (PSVOR). The new redundant interface J-box is a modification of the interconnection box used with the Titan engines instrumentation kits. The instrumentation kit interconnecting box is designed to withstand a vibration environment of 43g rms, combined sinusoidal and random.

It is concluded from the low vibration profile of Figure 38 (approximately 6.7g rms Gaussian combined with 5.3g rms sinusoidal at 1360 Hz) that a considerable design safety margin exits for the redundant interface J-box.

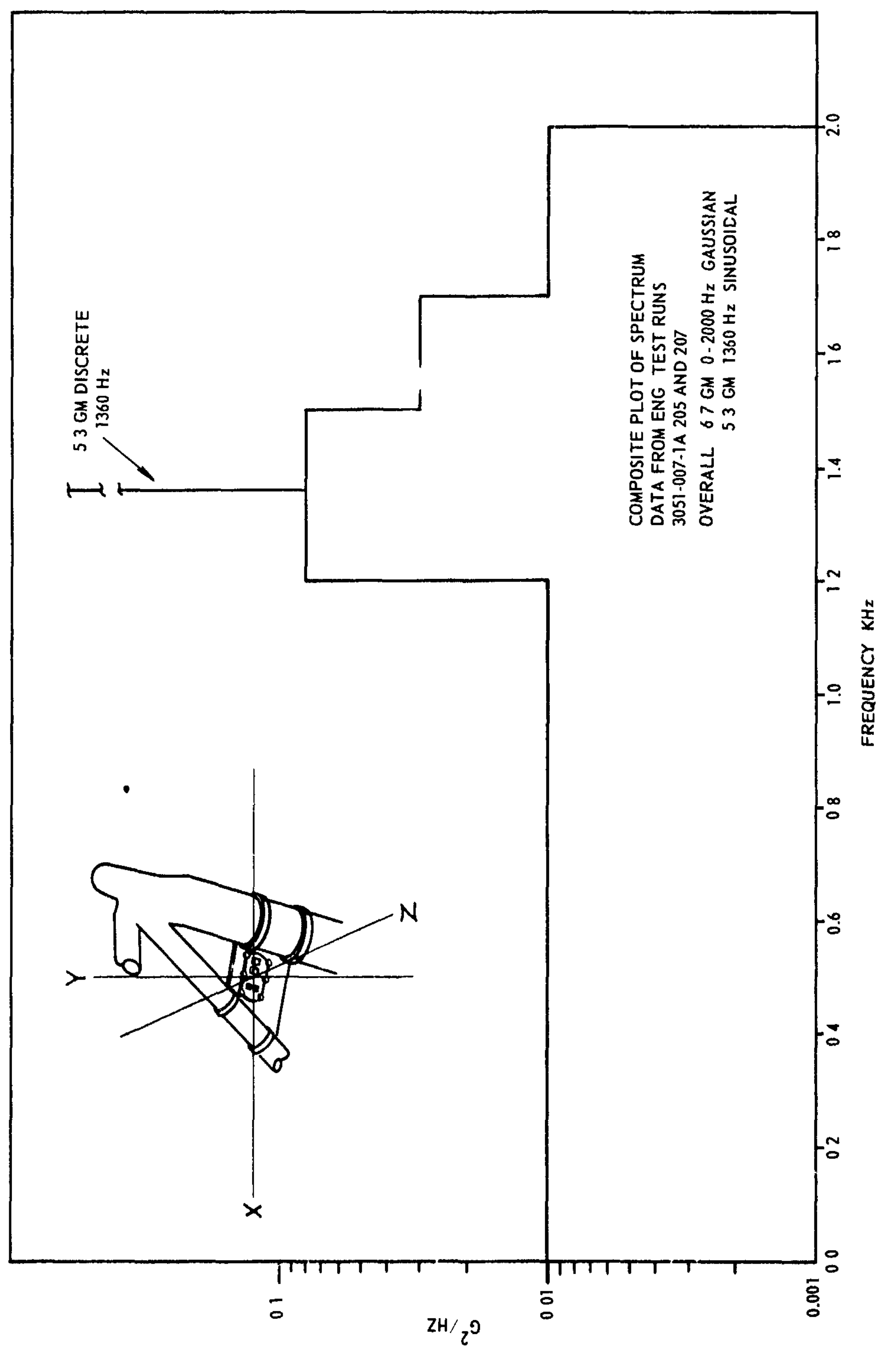


Figure 38 -- Vibration Environment -- Redundant Interface J-Box

3.1, Engine Performance (cont.)

Fuel Cavitation Suppression

The gas generator fuel control venturis normally operate in a fully cavitating flow condition. On two demonstration tests cavitation was intentionally suppressed in order to demonstrate continued engine operation and control under this peripheral condition. These tests were desired because of the possibility that during high thrust operation of the Titan IIIM Stage I engine, the increase in gas generator fuel flow rate could result in suppressing cavitation in the venturi, particularly with the additional required flow rate to the gas generator required to operate the 83-blade turbine rotor (explained in a later section).

Attempts to suppress cavitation were made on three tests by installating an orifice downstream of the venturi. The first attempt, Test No. -215, failed to suppress cavitation; attempts on Tests No. -315 and No. -316 succeeded. Table 26 summarizes the results of these attempts. The same venturi was used in the three tests, as well as in a base test with no restricting orifice. The venturi was relatively large (KFBTV-0.435) and was installed in Subassembly 2, which has less operating margin for maintaining cavitation since it requires a higher gas generator fuel flow rate than Subassembly 1.

An index of the venturi operation is the pressure ratio across the venturi. At higher pressure ratios the venturi is assumed to be cavitating, and therefore desireably insensitive to downstream pressures. (The point of cavitation suppression is determined by hydrotest calibration for the particular venturi.) To obtain a more accurate understanding of bootstrap system operation, a special pressure tap fitting was installed at the inlet to the fuel check valve (PFCKV). This pressure was monitored during the latter part of the demonstration tests.

Table 26 -- Cavitation Suppression Tests
Titan IIIM Demo Engines

Test	-208	-215	-315	-316
Engine subassembly	Demo 14, SA 2	Demo 14, SA 2	Demo 15, SA 2	Demo 15, SA 2
Total pressure, psia				
Venturi inlet	1201	1220	1119	1113
Venturi outlet	1013	1094	1041	1035
Pressure ratio, PRV				
Suppression point	0.904	0.904	0.904	0.904
Actual	0.843	0.897	0.930	0.930
Difference	0.061	0.007	-0.026	-0.026
WFGG, lb/sec	14.24	14.56	13.0	13.0
Thrust, lb	268,500	280,660	260,500	262,470
Shaft horsepower	5,682	5,789	4,908	4,837
Orifice Delta P, psi	None	60-65	200-210	200-210
Venturi operation	Normal cavitation	Cavitation not suppressed but marginal	Cavitation suppressed	Cavitation suppressed

Actual data, 2 sec - FS_2 time period

Fuel venturi S/N 393, KFBTV = 0.438 (latest calibration)

3.1, Engine Performance (cont.)

Referring to Table 26, in the base Test No. -208 with no restrictive orifice downstream, the venturi produced thrust 6.5% above nominal. The actual pressure ratio was 0.843 compared to the suppression ratio of 0.904 for that particular venturi. PFCKV was not instrumented during this test; the pressure was estimated from the check valve resistance obtained from later tests. On the final test of engine S/N 14 (Test No. -215), an attempt was made to suppress cavitation using a 0.618-inch diameter orifice, but the orifice pressure drop of approximately 65 psi was less than desired, and the test ran at high thrust (+8.0%). The actual pressure ratio had increased to 0.897, but was still less than the suppression point of 0.904. On Tests Nos. -315 and -316 with engine S/N 15, cavitation was successfully suppressed by the use of a 0.500-inch orifice, introducing about 200 psi pressure drop. The venturi pressure ratio increased to 0.930, or 0.026 above the suppression point. The thrust from Subassembly 2 was approximately 4% below what it would have been with cavitating flow in the fuel venturi. All parameters appeared to be normal and stable throughout the 20-second and 200-second tests, and the transient appeared normal. No problems were encountered in the suppressed cavitation tests, except for the difficulty in obtaining the desired pressure drop across a sharp edged orifice located in a non-calibrated system.

In Figure 39 the actual venturi pressure ratios and the suppression points are plotted vs the fuel flow rates, WFGG, for all the tests with PFCKV instrumented, plus Test No. -208. The connecting vertical lines in the figure indicate the margin of cavitation, and illustrate how the margin decreases with the increased demand for WFGG, which is proportional to turbine horsepower requirements. The two tests, Nos. -315 and -316, with artifically suppressed cavitation, are shown at a value on the abscissa of 13 lb/sec (WFGG), which was estimated by using the pressure drop across the gas generator fuel injector and the average resistance as derived from other tests with this injector where the flow rate was known.

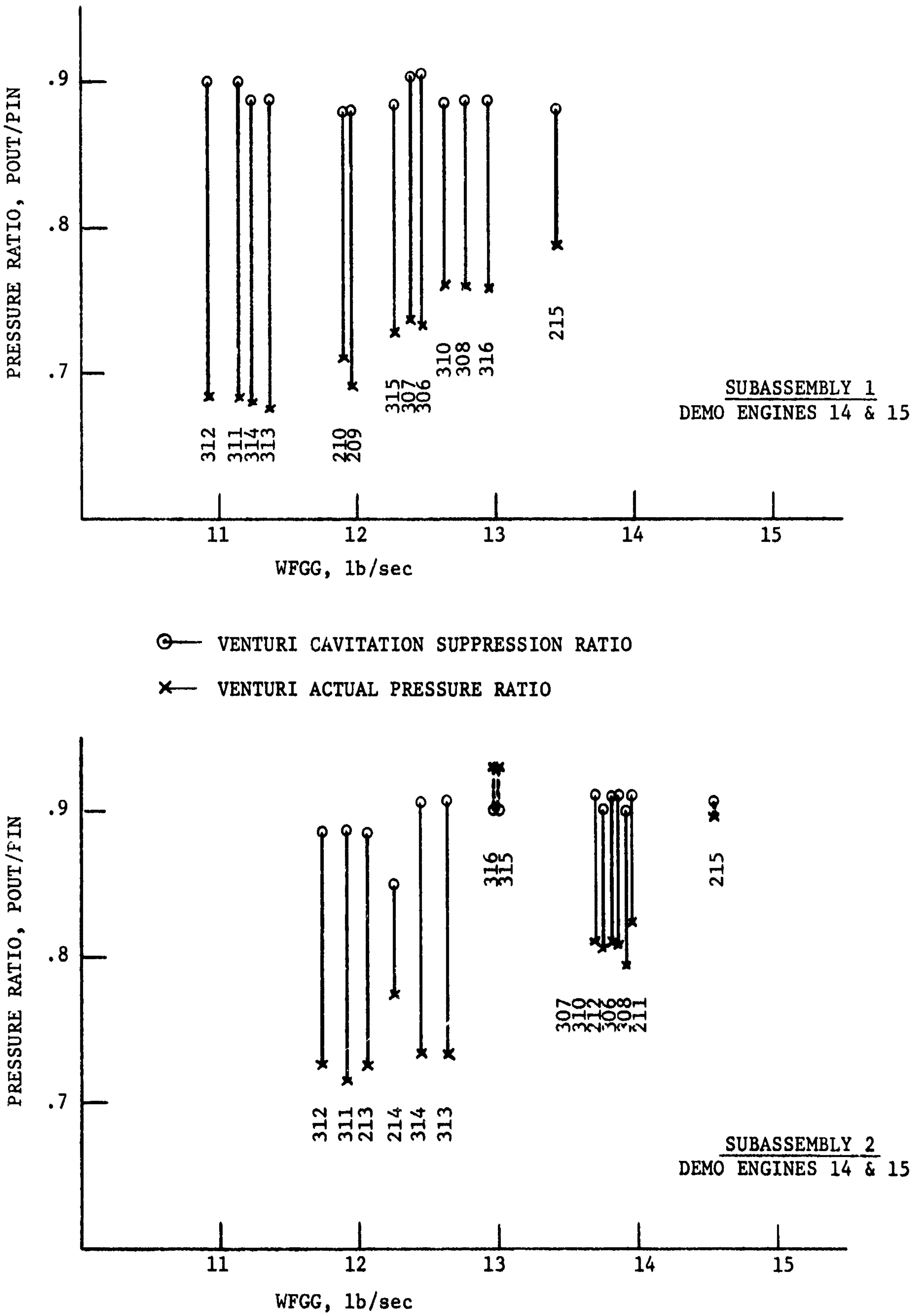


Figure 39 -- Fuel Venturi Suppression Ratios
Titan IIIM Demo Tests

3.1, Engine Performance (cont.)

Fuel System Gas Bubble

Early during Test No. -204 all parameters deflected momentarily, then recovered to normal operating levels. The test continued in a normal manner until a turbine rotor failure caused shutdown. The rotor failure was unrelated to the demonstration test objectives and is discussed in a subsequent paragraph.

Following a normal start transient and achieving steady-state, engine performance at Fire-Switch 1 (FS1) plus 2.6 second, decayed for approximately 2 seconds duration. After recovery, the engine proceeded to operate normally until 115.44 seconds, at which time the first rotor on Subassembly 2 failed and the test was terminated.

A post fire review of the records indicated that a gas bubble had passed through the fuel system. This was evidenced by a rapid acceleration of the fuel flowmeters accompanied by decreased suction pressures.

As this was the fourth test on a recently modified system and no prior anomalies had been noted while using the same checklist procedures during prefire and countdown, an investigation was initiated to identify the cause of the gas bubble. Calculations of line volume indicate the location of the gas bubble as being in the vicinity of the test stand safety valves prior to FS1. The following items could contribute to this condition: (1) improper bleed-in, (2) suction line purges, (3) GN_2 leakage, (4) the systems common with Test Stand G-1 and (5) the drain manifold system.

The bleed-in procedure was checked and it was verified by three separate monitors that the procedure had been performed correctly as shown on the FMFBV meter (this signal is obtained from a 1-1/4 in. flowmeter located immediately downstream of the high point bleed valve.

3.1, Engine Performance (cont.)

The suction line purges were checked out; because of an interlock they cannot be energized "ON" at any time the main safety valves are open. This interlock was working correctly.

The possibility of GN_2 leakage into the suction line, when the purge pressures are set up, was checked for leakage past the valves and no leakage was found. The Test Stand G-1/G-2 common systems were checked and no indication of leakage past the Test Stand G-1 safeties was noted.

The drain manifold system was then checked with the dump tank pressurized, as fuel is normally loaded with the dump tank pressurized to 70 psig. It was found that with the dump tank inlet valve opened, it is possible to get leakage back through the high point bleed system, but in the reverse direction. For this to have occurred, two conditions were necessary: (1) a pressure lockup of 70 psig left in the manifold, and (2) the inlet valve in the "closed" position. This situation did not exist as evidenced by the proper check-off of the procedures on the check list.

Based on the foregoing investigation and inconclusive results, corrective action initiated prior to the next test was as follows:

a. An additional bleed-in cycle was inserted in the countdown procedure.

b. The leaking check valve in the drain manifold line was repaired and an additional check valve installed immdediately downstream of the high point bleed valve and flowmeter to prevent a possibility of a reverse flow in the "high point" bleed line.

No recurrence of this anomaly was noted during the remainder of the test series.

3.1, Engine Performance (cont.)

Oxidizer Autogenous Increased Flow Tests

Some of the engine demonstration tests were utilized to obtain oxidizer superheater performance data at increased pressurant flow rates, as a follow-on to CCN 59. This contract change was a study to determine the extent that the oxidizer pressurant flow rate of the existing superheater system could be increased, with the ultimate objective of providing higher oxidizer tank pressure. The Final Report for CCN 59 (Reference 5) predicted a capability shown as the limits box on the right side of Figure 40 with the current limits box shown on the left. Because the new flow limits were based on extrapolations of earlier Titan test data into a new region of operation, actual tests were recommended at the increased flow rates. A series of tests, tentatively approved on a non-interference basis, was conducted in conjunction with the remaining demonstration tests, and additional tests were scheduled for performance with future R&D engine tests. Soon after the demonstration phase of the tests was accomplished, the CCN follow-on effort, including analysis, was terminated. No other report is planned, so the subject tests are briefly summarized.

All the special autogenous tests are shown in Figure 40. They include ten tests with engine S/N 15 and the final test with engine S/N 14. The tests were conducted with the superheater bypass lines blanked off to attain maximum enthalpy. Two base tests, Nos. -305 and -306, were conducted at nominal flow (WOP/VOS). The flow was then increased for a number of tests, using three large venturis (KOPV). The venturi size was reduced to an intermediate value for Test No. -314.

The dashed line in Figure 40 indicates the expected enthalpy vs flow characteristic for closed bypass operation, as predicted in the CCN 59 report. It can be seen that the tested values of enthalpy dropped off at a higher rate then expected.

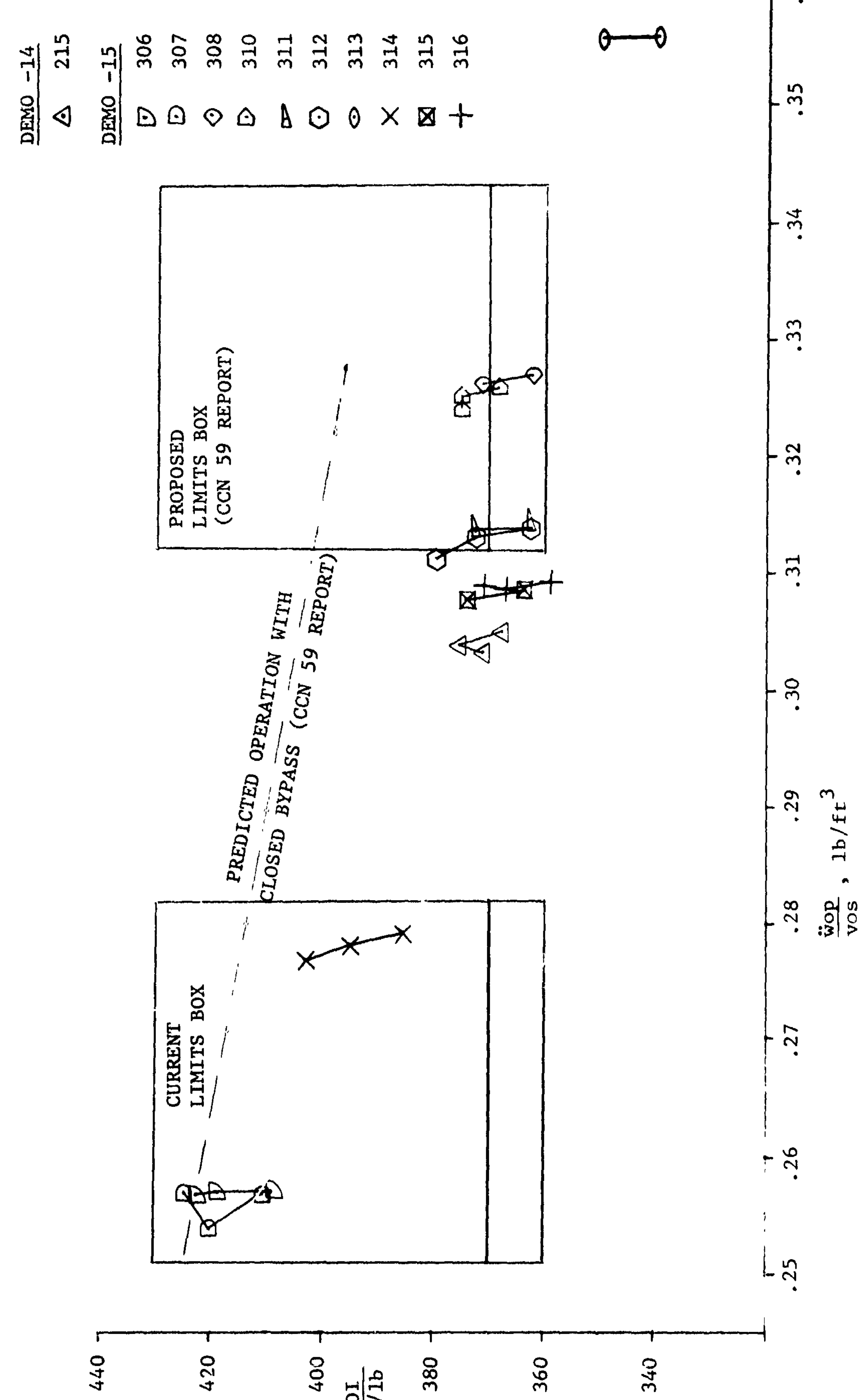


Figure 40 -- Oxidizer Autogenous Increased Flow Tests

3.1, Engine Performance (cont.)

It should be noted that the increased flow tests were also in conjunction with the engine demonstration peripheral tests, and therefore, to compare the various points, the enthalpy and flow values in Figure 40 should be normalized for nominal thrust, mixture ratio and propellant temperature. This was to have been part of the now discontinued analysis effort, but it is apparent that even with this correction of the data, the enthalpy would still be lower than predicted.

3, Data and Component Evaluations (cont.)

3.2 ENGINE COMPONENTS

3.2.1 Frame Assembly, P/N 1129050-19

The engine frame was redesigned to provide for increased loads and reorientation of the thrust centerline from 2° 1' to 3' - 0'.

Frame S/N 605 accrued 1824 sec duration from 15 engine tests. Of these, eight tests were of 200 sec duration each.

Frame S/N 606 accrued 2114 sec duration from 16 engine tests. Of these, ten tests were of 200 sec duration each.

During the program there were no discrepancies or anomalies associated with the frame. Post-program examination found both frames free of distortion and suitable for reuse.

3.2.2 Oxidizer Bootstrap Hose, P/N 1131888

The oxidizer bootstrap hose was redesigned to incorporate end fitting nuts that are drilled for lockwire and to provide a hose fabricated from conducting-type teflon to reduce the possibility of leakage caused by electrostatic discharge through the teflon.

Bootstrap hoses S/N 1604 and S/N 1605 on Subassemblies 1 and 2 respectively, accrued 1824 sec total duration from 15 engine tests with engine S/N 14. Of these, eight tests were of 200 sec duration each.

Bootstrap hoses S/N 1608 and S/N 1609 on Subassemblies 1 and 2 respectively, accrued 2114 sec total duration from 16 engine tests on engine 15. Of these, ten tests were of 200 sec duration each.

3.2, Engine Components (cont.)

During the program, there were no discrepancies or anomalies associated with any of the lines; post-program examination found the lines free of distortion and suitable for reuse.

3.2.3 Ablative Skirts, (15:1)

Ten ablative skirts were tested on demonstration engines and during each test the thrust chamber assembly was gimballed. On each test the external surfaces of the combustion chambers and ablative skirts were protected by Government furnished insulation panels.

The only damage noted on any of the skirts was a small spot of erosion on skirt S/N 021. Generally, all skirts had heat discoloration of the outer laminate surfaces. The colors varied from dark brown to black. The discoloration is attributed to the baking effect under the insulation panels after the test is terminated. Following each test there is a period of approximately 1.5 to 2.0 hours before the insulating panels can be removed and during this period, due to heat soak from the skirt and from the turbine exhaust, skirt external surface temperatures reach approximately 800°F.

On the skirts that were instrumented with backside liner and external surface thermocouples, all design criteria requirements were met. Posttest sectioning and chemical depth analyses revealed no unusual problems.

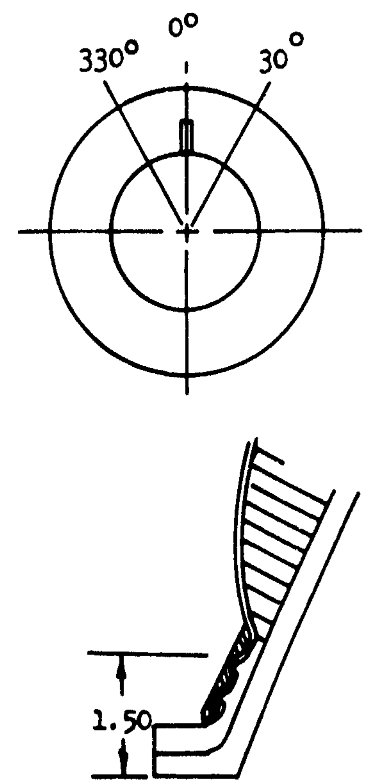
Ablative Skirts S/N 025 and S/N 037

Ablative skirts S/N 025 and S/N 037 were tested twice during the demonstration test program. The first test, No. -204, was terminated after 115.438 seconds of firing because of problems which developed in the turbopump system. The two units were subsequently retested for 201.040 seconds during Test No. -206. Both units were intact after shutdown.

Table 27 -- Ablative Skirt Flange Temperature--
Skirts 014 and 021

Time, Seconds	Temperature °F					
	1TAS-1	1TAS-2	1TAS-3	2-TAS-1	2TAS-2	2TAS-3
0	92	94	98	93	92	91
20	90	92	97	99	97	89
40	92	102	100	100	127	100
60	94	123	97	104	135	102
80	98	112	102	112	144	106
100	96	128	93	122	136	105
120	98	--	97	130	146	109
140	103	--	105	140	146	112
160	101	--	93	157	137	113
180	107	110	109	167	143	118
200	110	--	107	176	141	126
216	122	133	116	205	139	117

Thermocouple Location Diagram



NOTE: Thermocouples 1TAS-1, 2, 3 were mounted on skirt SN 014 #1 Subassembly.
Thermocouples 2TAS-1, 2, 3 were mounted on skirt SN 021 #2 Subassembly.

3.2, Engine Components (cont.)

Ablative Skirts S/N 032 and S/N 033

Ablative skirts S/N 032 and S/N 033 were fired for 200.591 seconds during Test No. 3051-D07-1A-215. The test was conducted at high thrust, low mixture ratio conditions. Both units were intact after testing. No postfire anomalies were noted.

Ablative Skirts S/N 035 and S/N 038

These skirts were tested during Test No. -305 for 200.6 sec at nominal engine conditions. Both skirts were intact following the test and only heat discolorations were noted on the exterior surfaces. Neither skirt was instrumented for the test or sectioned following the test.

Ablative Skirts S/N 014 and S/N 021

These skirts were tested during Test No. -307 for 200.5 sec. Engine thrust and mixture ratio varied throughout the test as turbopump inlet conditions were frequently adjusted to meet the NPSH objectives. Both nozzles were intact after the test and exhibited the usual heat discolorations on their exterior surfaces. Skirt S/N 021 had a small shallow area of erosion on the inside periphery of the forward flange.

Three thermocouples were attached to the roving of the aft flange. The location of the thermocouples and recorded temperatures are presented in Table 27.

Skirt S/N 014 had been used previously for exit closure expulsion tests and was reworked to plug three pressure tap holes. Some normal charring was evident around these locations.

Table 28 -- Performance and Conditions, Test 3051-D07-1A-316, Skirts SN 039 and 040

Test Parameter	SA 1	SA 2
Duration, sec	200.8	200.8
TCA mixture ratio	2.072	2.115
TCA weight flow, lb/sec	891.3	873.5
Chamber pressure, psia	838.4	814.8
Post, psia	108.2	114.6
Pfst, psia	29.94	34.01
Propellant temperature °F fuel/oxidizer	37/38	38/37
Altitude thrust (calc), lb	272,500	262,500
Max FS_2 liner temperature, °F	344	376
Gimbal duration, sec	32.46	32.46

3.2, Engine Components (cont.)

Ablative Skirts S/N 039 and S/N 040

These were the first 15:1 skirts fabricated at the Aerojet-General facilities. They were tested during Test No. -316 for 200.8 sec. The test was conducted with the engine operating at peripheral mixture ratio and thrust conditions.

The test conditions and performance obtained during the test which directly affect the skirt operation and condition are presented in Table 28.

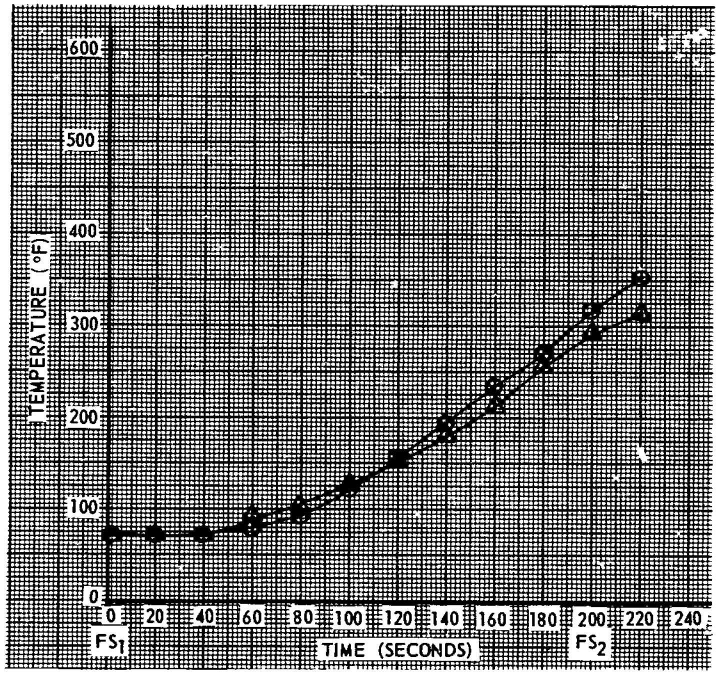
The ablative skirts were instrumented with three liner backwall thermocouples and one outer laminate thermocouple. The location and recorded temperatures are presented in Figure 41. The recorded outer laminate temperatures and locations are presented in Figure 42.

Visual inspection of the skirts indicated normal char patterns. Streaking and circumferential cracking were moderate with no serious anomalies noted. The outer laminates of both units were discolored from the postfire heat contained by the Refrasil insulation panels. Three bulges were noted on skirt S/N 039 indicating some delamination. One similar bulge was noted on nozzle S/N 040. The delamination is attributed to the liner shrinking during the cooldown period rather than because of gas pressure since the honeycomb is perforated and vented to the atmosphere.

The Stage I ablative nozzle weight loss for a 200 sec test is approximately 36 lb. For extended durations beyond 200 sec the weight loss can be estimated as 0.17 lb/sec. The weight loss for this test is shown as follows:

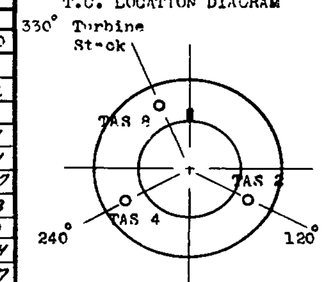
Nozzle S/N	Pretest Weight, lb	Posttest Weight, lb	Weight Loss, lb
039	415	376	31
040	418	387	39

PART NO. 1155706-1
SERIAL NO. 0000039 and 0000040
TEST NO. 3051-D07-1A-316



LINER BACKWALL TEMPERATURES F°								
Time Seconds	TAS-2		TAS-4		TAS-8		AVG.	
	039	040	039	040	039	040	039	040
FS1	72	72	74	71	72	72	○	△
20	73	73	73	72	72	72	73	72
40	74	74	74	72	74	73	74	73
60	80	122	77	77	80	80	79	94
80	98	126	85	89	100	97	93	104
100	127	147	107	111	129	122	121	127
120	165	165	135	139	166	154	155	153
140	207	178	167	172	207	190	194	180
160	252	207	204	207	246	228	234	214
180	297	184	240	246	283	267	273	257
200.9	344	376	279	283	324	303	316	293
220	358	443	308	304	360	322	352	313
W-11 Thick In.	.721	.705	.720	.700	.717	.701	.719	.703

T.C. LOCATION DIAGRAM



All liner TC's located 20in. aft of fwd. flange.

Note: Thermocouples on S/N-039 skirt are located 20 inches below the forward flange. Thermocouples on S/N-040 skirt are located 22 inches below the forward flange.

Figure 41 -- Ablative Liner Backwall Temperature -- Skirts S/N 039 and S/N 040

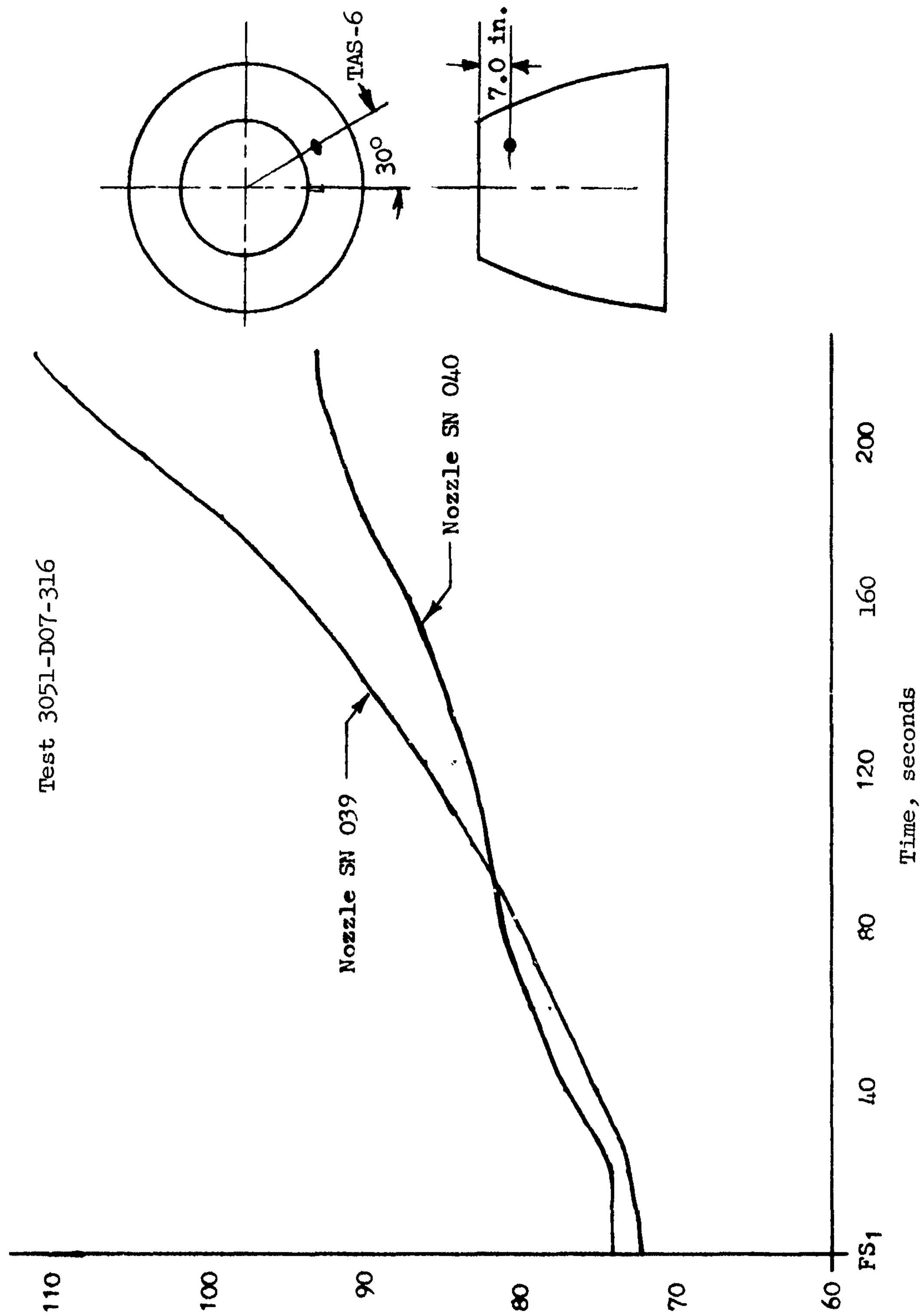


Figure 42 -- Outer Laminate Temperatures, Skirts 039 and 040

3.2, Engine Components (cont.)

Sonic tests were performed on both nozzles to evaluate the integrity of the honeycomb support structures. The tests indicated that skirt S/N 039 had delamination in eight areas. These areas were detected at 460, 500 and 550 cps ranges (see Figure 43).

Skirt S/N 040 showed a single delamination at 180 degrees when tested at the lower frequencies. At frequencies of 4K to 6K cps, the structure appeared to be delaminated peripherally 8-in. below the forward flange (see Figure 44).

Both skirts were sectioned for the evaluation of structural condition and the measurement of liner char depths. Each skirt was sectioned at six longitudinal stations. The location of these stations, referenced to the injector, and the remaining uncharred thicknesses are presented in Figures 45 and 46. A circumferential cut was made at the midsection of each skirt. This cut was made through the thermocouples located 20 in. from the forward flange on skirts S/N 039 and 22 in. from the forward flange on skirt S/N 040. It was noted that charring was less in areas under the baffle legs than in areas between baffles. The longitudinal linear measurements are presented in Figures 47 and 48.

3.2.4 Refrasil Insulation Panels

Two sets (12 panels) of GFP Refrasil insulation panels were utilized for most of the engine demonstration test program. For the last test on engine S/N 15 one engine subassembly was equipped with a new set (3 panels). A total of seven tests were conducted using the insulation panels for an accumulated duration of 1319.7 seconds. Four of the tests were conducted with engine S/N 14 for an accumulated duration of 717.8 seconds and three tests were conducted with engine S/N 15 for an accumulated duration of 601.9 seconds.

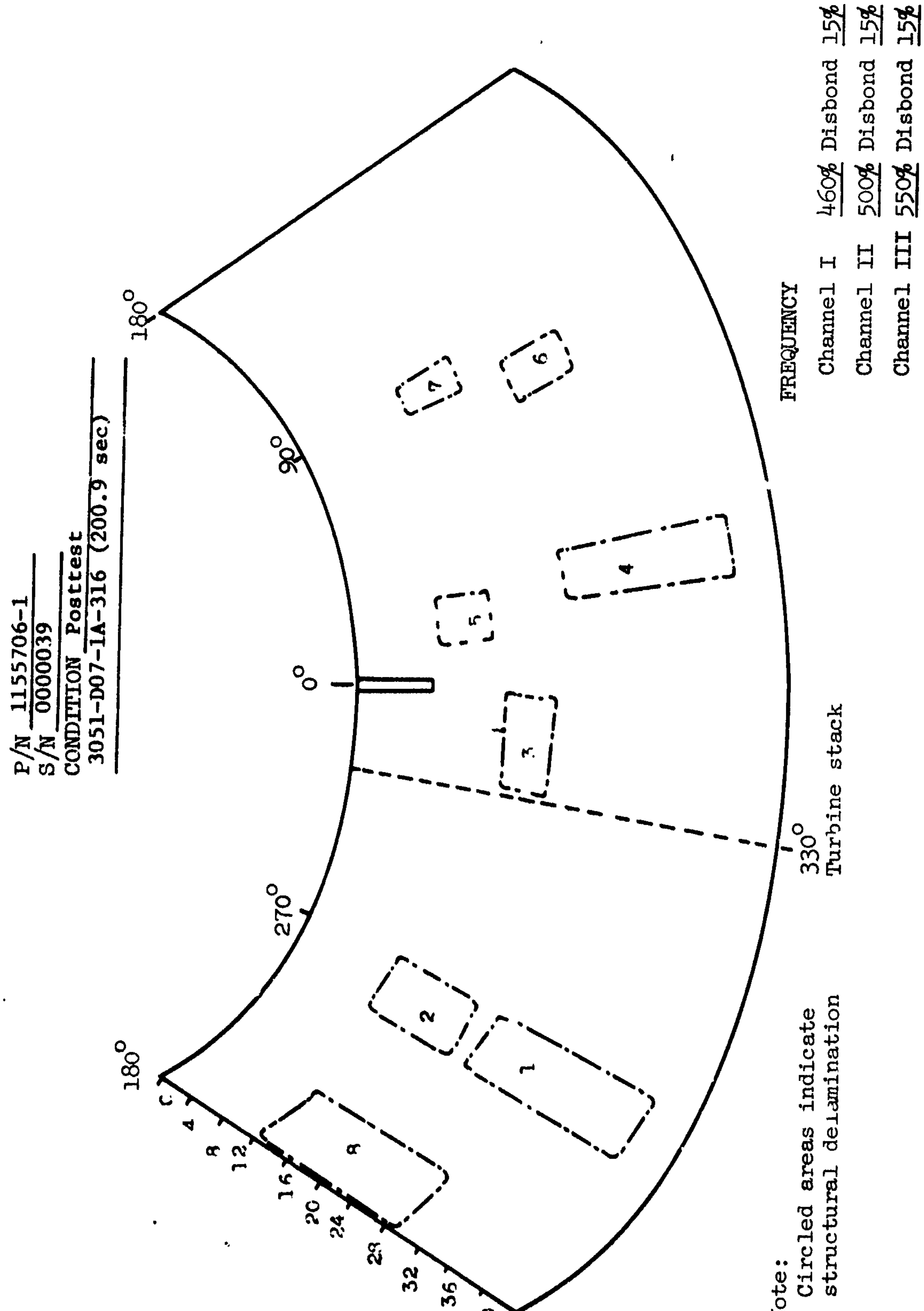


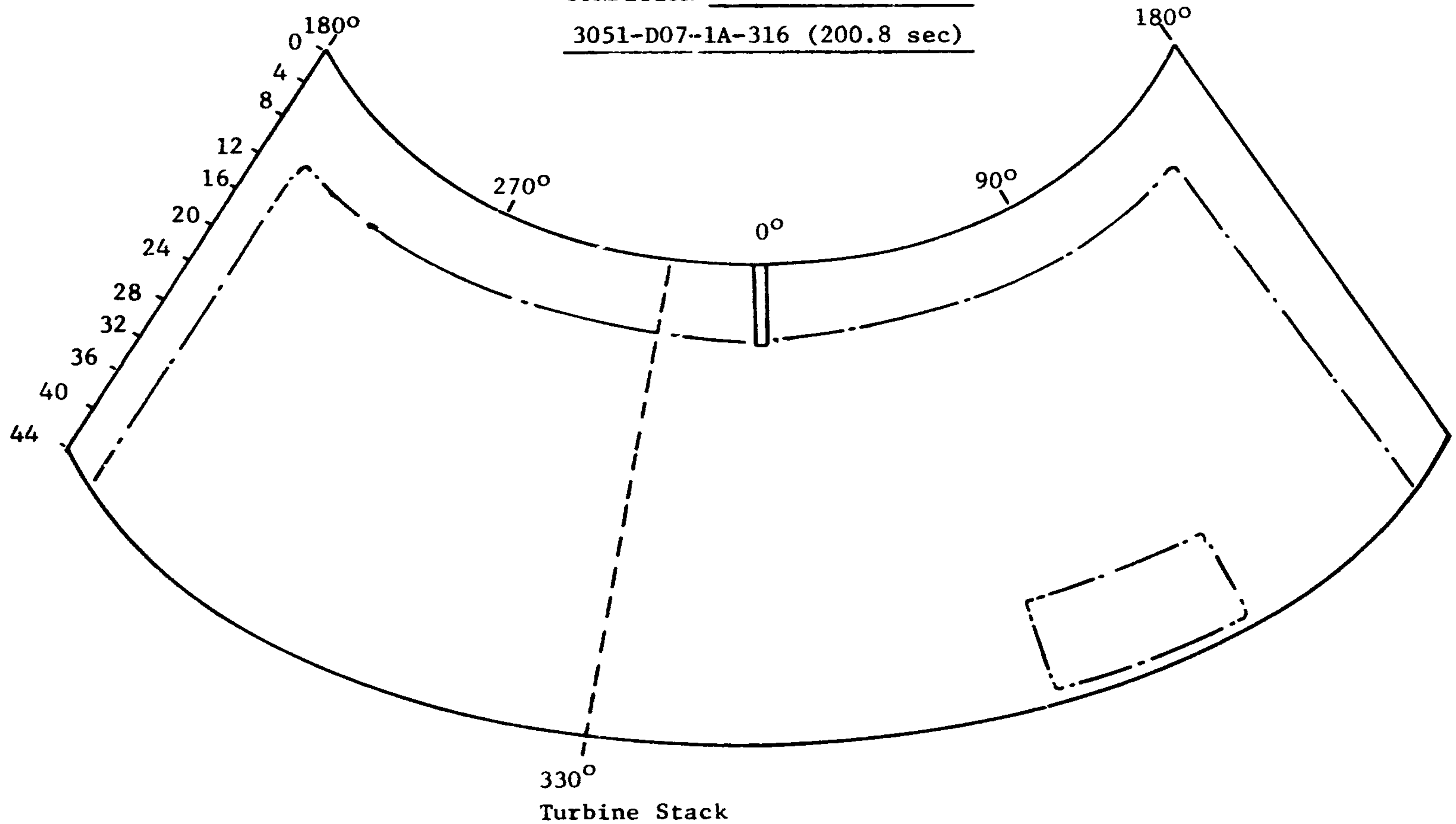
Figure 43 -- Sonic Tap Test, Skirt 039

P/N 1155706

S/N 0000040

CONDITION Posttest

3051-D07-1A-316 (200.8 sec)



NOTE:

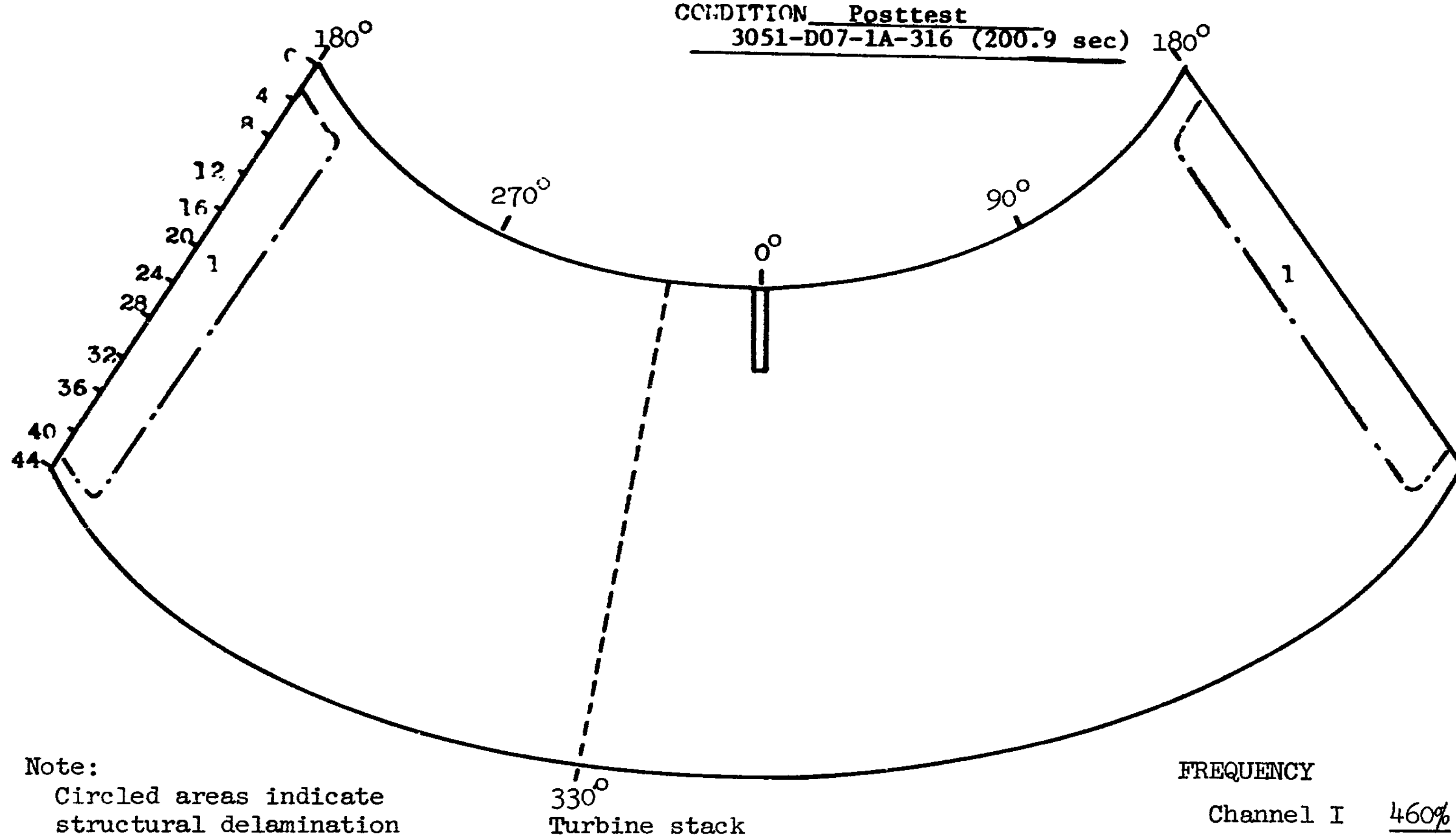
Circled areas indicate
Structural Delamination

FREQUENCY

Channel I	3K-8K%	Disbond	-
Channel II	4K-6K%	Disbond	-
Channel III	3.8K-4K	Disbond	-

Figure 44 -- Sonic Tap Test, Skirt 040

P/N 1155706-1
S/N 0000040
CONDITION Posttest
3051-D07-1A-316 (200.9 sec)



Note:
Circled areas indicate
structural delamination

FREQUENCY

Channel I 460% Disbond 17°
Channel II 500% Disbond 17°
Channel III 550% Disbond 17°

Figure 44 - Sonic Tap Test, Skirt 040

Measured 20 inches from the Mounting Flange

Test No. 3051-D07-1A-316

Ablative Skirt S/N 0000039

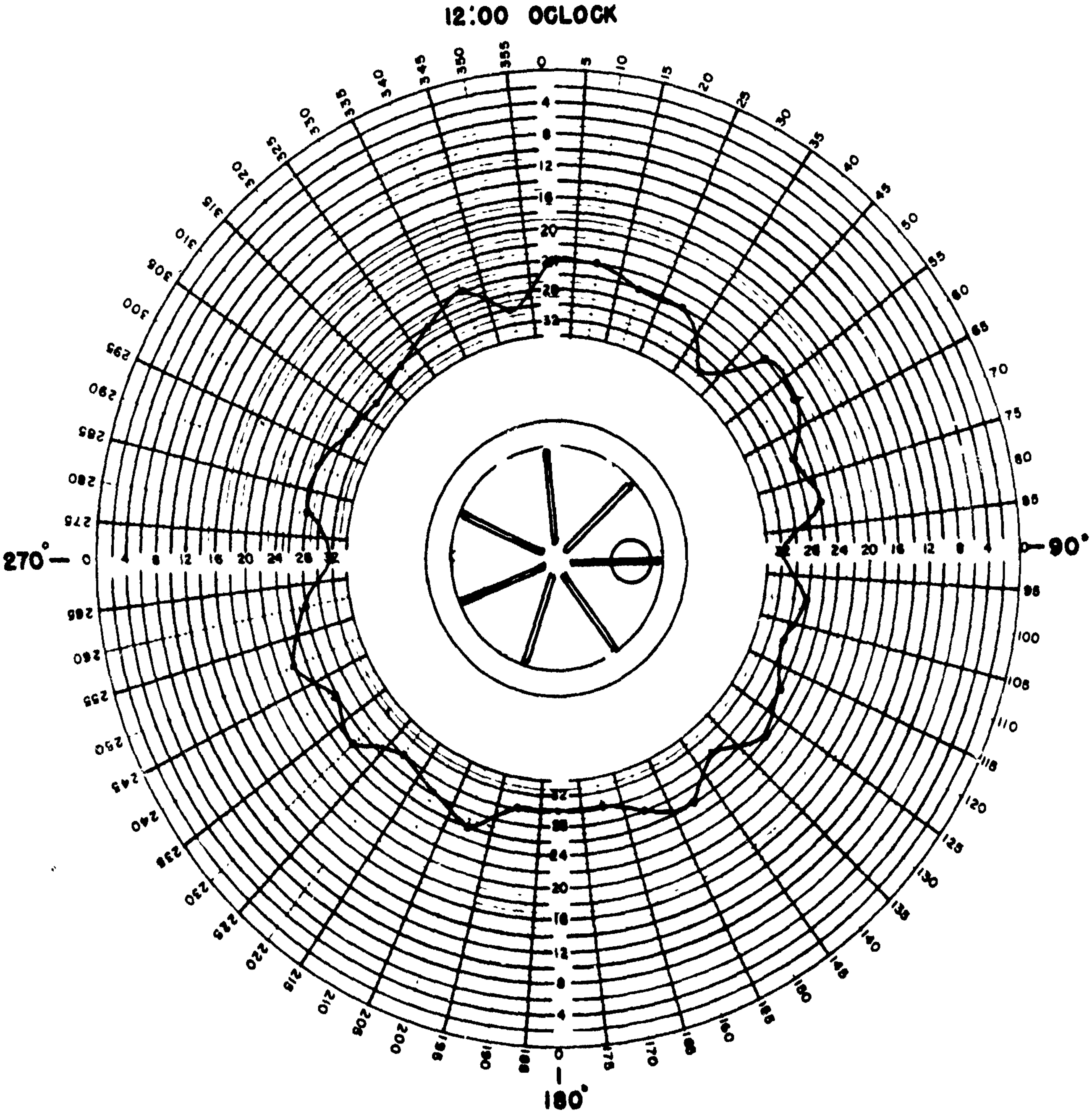


Figure 45 -- Circumferential Char Penetration, Skirt 039

Circumferential Char Penetration Measured 22 inches from the Mounting Flange

Test No. 3051-D07-1A-316

Ablative Skirt S/N 0000040

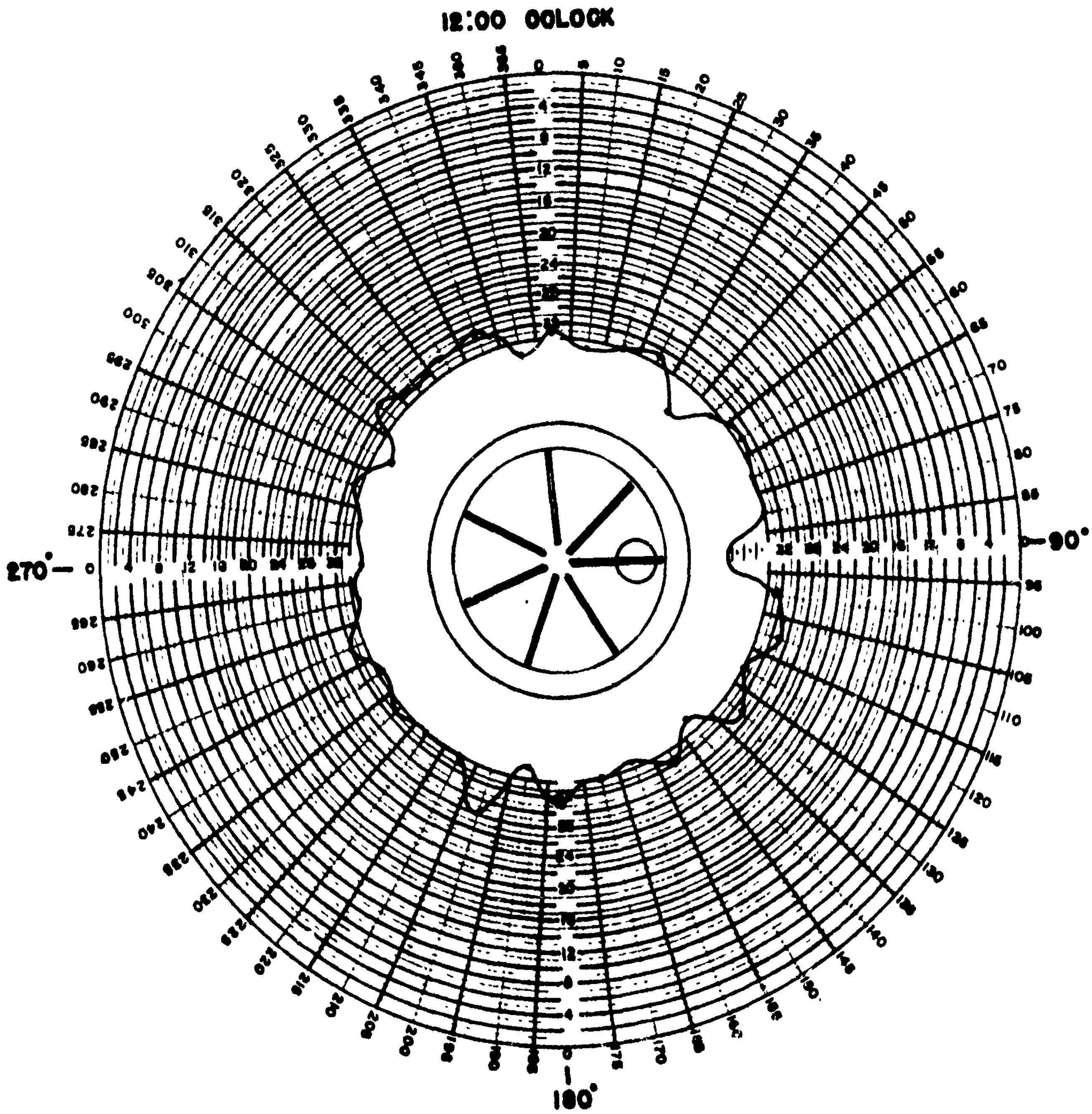


Figure 46 -- Circumferential Char Penetration, Skirt 040

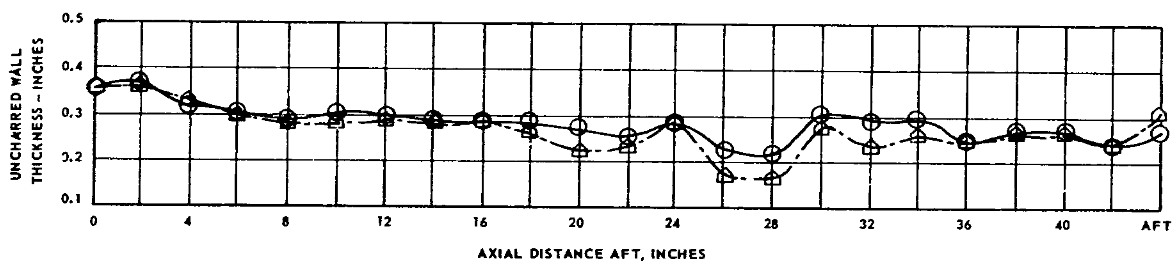
SKIRT P/N 1155706-1 SKIRT S/N 0000039

Distance Aft Inches	INJECTOR REFERENCE: Near Baffles #1, #4 and #5 TAS #4 Located 240°									
	190°		240°		25°		257°		Average	
	Unch	Tot	Unch	Tot	Unch	Tot	Unch	Tot	Unch	Tot
Fwd	.40	.74	.33	.75	.36	.76	.36	.76	.36	.75
2	.42	.76	.35	.76	.34	.78	.39	.77	.37	.77
4	.36	.76	.26	.76	.30	.76	.34	.76	.31	.76
6	.34	.74	.30	.75	.26	.76	.31	.75	.30	.75
8	.32	.74	.29	.75	.26	.76	.29	.75	.29	.75
10	.34	.74	.30	.76	.27	.77	.29	.77	.30	.76
12	.34	.74	.30	.76	.29	.78	.26	.76	.30	.76
14	.32	.72	.30	.75	.27	.77	.29	.75	.29	.75
16	.30	.72	.29	.74	.26	.76	.27	.75	.28	.74
18	.32	.72	.29	.74	.24	.76	.26	.74	.28	.74
20	.29	.71	.25	.73	.22	.73	.21	.73	.27	.73
22	.29	.72	.25	.73	.25	.75	.21	.72	.25	.73
24	.25	.73	.33	.74	.27	.75	.28	.74	.28	.74
26	.25	.69	.22	.71	.28	.72	.15	.71	.22	.71
28	.26	.70	.21	.72	.22	.74	.16	.72	.21	.72
30	.33	.71	.27	.73	.29	.75	.20	.74	.30	.73
32	.31	.69	.29	.72	.26	.74	.26	.72	.28	.72
34	.31	.69	.29	.72	.28	.73	.27	.72	.29	.72
36	.27	.68	.24	.70	.22	.72	.23	[illegible]	.24	.70
38	.31	.69	.26	.70	.26	.72	.25	.70	.27	.70
40	.31	.69	.29	.71	.24	.70	.24	.70	.27	.70
42	.28	.68	.27	.70	.22	.70	.25	[illegible]	.23	.70
Aft	.34	.72	.33	.73	.13	.73	.34	.74	.26	.73

NOTE: Unch = Uncharred depth
Tot = Total thickness

TEST NO. 3051-D07-1A-316

INJECTOR REFERENCE: Between Baffle #4 and #5 and #6 and #7					
230°		120°		Average	
Unch	Tot	Unch	Tot	Unch	Tot
.36	.76	.35	.75	.36	.76
.36	.76	.35	.76	.36	.76
.30	.75	.33	.76	.32	.76
.29	.75	.30	.74	.30	.75
.26	.74	.29	.75	.28	.75
.29	.77	.26	.76	.28	.76
.27	.75	.30	.76	.28	.76
.27	.75	.30	.76	.28	.76
.26	.75	.30	.76	.28	.76
.24	.74	.29	.74	.26	.74
.20	.74	.24	.74	.22	.74
.20	.74	.26	.74	.23	74
.26	.74	.30	.76	.28	.75
.14	.72	.20	.72	.17	.72
.14	.72	.18	.72	.16	.72
.24	.72	.30	.74	.27	.73
.22	.70	.25	.71	.23	.71
.26	.72	.24	.70	.25	.71
.22	.70	.26	.70	.24	.70
.25	.71	.27	.71	.26	.71
.24	.70	.28	.70	.26	.70
.22	.70	.25	.69	.23	.70
.28	.72	.32	.70	.30	.71



Injector Ref. Avg. Uncharred △

Injector Ref. Avg. Uncharred ○

Figure 47 -- Longitudinal Thickness Profile, Skirt 039

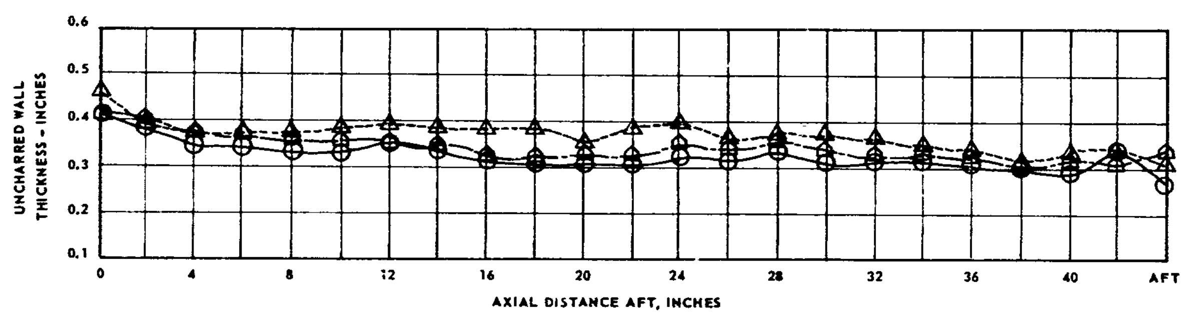
SKIRT P/N 1155706-1 SKIRT S/N 0000040 TEST NO. 3051-D07-1A-316

Distance Aft Inches	INJECTOR REFERENCE Near Baffles #4 and #2 240° Unch	240° Tot	330° Unch	330° Tot	Average Unch	Average Tot
Fwd	.40	.79	.41	.77	.41	.78
2	.37	.79	.38	.77	.38	.78
4	.31	.78	.37	.77	.34	.78
6	.31	.78	.37	.78	.34	.78
8	.30	.79	.35	.77	.33	.78
10	31	.78	.35	.76	.33	.77
12	33	.79	.36	.77	.35	.78
14	.31	.79	.34	.76	.33	.78
16	.29	.79	.33	.76	.31	.78
18	.28	.78	.32	.76	.30	.77
20	.29	.77	.30	.74	.30	.76
22	.29	.77	.30	.75	.30	.76
24	.37	.78	.33	.75	.32	.76
26	.31	.78	.31	.74	.31	.76
28	.32	.76	.34	.74	.33	.75
30	.27	.76	.33	.73	.31	.75
32	.29	.75	.33	.73	.31	.74
34	.30	.74	.31	.72	.31	.73
36	.29	.73	.31	.72	.30	.73
38	.28	.72	.29	.71	.29	.72
40	.27	.73	.30	.71	.28	.72
42	.32	.73	.34	.73	.33	.72
Aft	.33	.73	.20	.72	26	.72

Distance Aft Inches	INJECTOR REFERENCE Between Baffles 62° Unch	62° Tot	118° Unch	118° Tot	176° Unch	176° Tot	Average Unch	Average Tot
Fwd	.43	.79	.39	.78	.40	.78	.41	.78
2	.41	.78	.40	.75	.38	.78	.40	.77
4	.41	.78	.37	.76	.34	.76	.37	.77
6	.37	.77	.36	.76	.35	.78	.36	.77
8	.35	.76	.35	.75	.34	.77	.35	.76
10	.39	.76	.35	.74	.33	.77	.36	.76
12	.37	.75	.36	.76	.33	.77	.35	.76
14	.37	.75	.34	.74	.32	.77	.34	.75
16	.34	.73	.30	.72	.33	.77	.32	.74
18	.34	.73	.29	.73	.33	.77	.32	.74
20	.31	.72	.32	.72	.32	.76	.32	73
22	.35	.75	.31	.74	.31	.75	.32	.75
24	.35	.74	.34	.74	.33	.76	.34	.75
26	.36	.73	.32	.70	.32	.75	.33	.73
28	.37	.75	.35	.74	.33	.75	.35	.75
30	.35	.73	.31	.71	.33	.73	.33	.72
32	.33	.70	.29	.69	.33	.74	.32	.71
34	.34	.71	.31	.71	.31	.73	.32	.72
36	.34	.70	.30	.70	.30	.72	.31	.71
38	.30	.68	.28	.68	.29	.71	.29	.69
40	.30	.70	.30	.71	.30	.72	.30	.71
42	.31	.70	.31	.71	.30	.72	.31	.71
Aft	.36	.70	.33	.70	.32	.72	.33	.71

Distance Aft Inches	INJECTOR REFEPENCE Under Baffle #1 38° Unch	38° Tot	Average Unch	Average Tot
Fwd	.47	.80	.47	.80
2	.39	.78	.39	.78
4	.37	.77	.37	.77
6	.37	.75	.37	.75
8	.37	.76	.37	.76
10	.38	.76	.38	.76
12	.39	.77	.39	.77
14	.38	.76	.38	.76
16	.38	.77	.38	.77
18	.38	.77	.38	.77
20	.35	.76	.35	.76
22	.38	.77	.38	.77
24	.39	.74	.39	.74
26	.36	.74	.36	.74
28	.37	.74	.37	.74
30	.36	.73	.36	.73
32	.36	.73	.36	.73
34	.34	.72	.34	.72
36	.33	.70	.33	.70
38	.31	.70	.31	.70
40	.33	.70	.33	.70
42	.33	.70	.33	.70
Aft	.31	.70	.31	.70

NOTE: Unch = Uncharred depth
Tot = Total thickness



Injector Ref. Avg. Uncharred ○
Injector Ref. Avg. Uncharred △
Injeccor Ref. Avg. Uncharred △

Figure 48 -- Longitudinal Thickness Profile, Skirt 040

3.2, Engine Components (cont.)

The condition of the insulation panels following each test was generally good with only heat discolorations, carbon deposits and stains evident on the exterior surfaces beneath the turbine exhausts (see Figure 49). Some dents and "oil-canning" were incurred during shipping and multiple test usage, but did not affect the serviceability of the units. Damage was incurred on one panel during the last test (-316) of engine S/N 15 which rendered the unit unsatisfactory for further use.

Except for the first test (No. -201) on engine S/N 14, the wire loops and lacing were made using 0.047 in. dia stainless steel lockwire since the panels were received without attachment hardware. A tight, snug fit at the panel seams was difficult to achieve without prelacing with a pliable cord. The stiffness of the lockwire endangered the capstans, particularily on reused panels, when attempting to draw the wire taut. Installation of the panels was very time consuming, especially to obtain tight snug fits. In addition to the many screws on the lower flanges (ablative skirt), there were 42 pairs of capstans on each seam that are loop-wired together prior to lacing. On each thrust chamber there are three seams. Therefore, on an engine assembly there were 252 pairs of capstans alone that required the loop-wiring before lace-wire was installed.

Test No. -204, Engine S/N 14

The Refrasil Panels were installed prior to test using 0.063 in. dia weld wire as specified on The Martin Company drawing 80802A92200. During the installation two capstans were pulled loose and three more were loosened. The postfire inspection disclosed the lacing on two seams had partially unraveled for 24 to 30 inches (see Figure 50). The wire was not broken nor were any wire-loops disconnected. No additional damage to the capstans was noted.

Figure 49 -- Refrasil Covers -- Engine S/N 15, Posttest

Figure 50 -- Refrasil Covers -- Engine S/N 14, Posttest

3.2, Engine Components (cont.)

Test No. -206, Engine S/N 14

The panels were installed 120° from their former position on the previous test. Postfire inspection disclosed the wire-lace again was unraveled on three seams for 20 to 26 inches. Some of the wire-loops at the same locations were unhooked. Three capstans at the maximum skirt diameter were found partially pulled out.

Test No. -214, Engine S/N 14

This test was conducted with 12:1 ablative skirts using modified 15:1 Refrasil Insulation Panels. The panels were shortened to match the skirt length and spot-welded to form an attachment flange and to retain the interior insulation material. The fit modifications were difficult and insufficient. A complete closure and attachment to the skirt exit flange could not be accomplished, consequently damage was sustained by both ablative skirts.

Test No. -215, Engine S/N 14

The panels were installed using a new procedure provided by The Martin Company. Dacron cord lacing was applied initially to tighten up and position the panels before wire-loops and lacing were applied. Although additional time was required the installation was an improvement over previous attempts. All wire-loops and lacing were intact after the test.

Test No. -305, Engine S/N 15

Postfire inspection disclosed some looseness on the wire-lacing of each seam. On the inboard seam (between chambers) of Subassembly 1, the wire-lacing was detached from eight capstans at the chamber flange level; however, the wire-loops on each pair were intact. There was no damage to the panels or

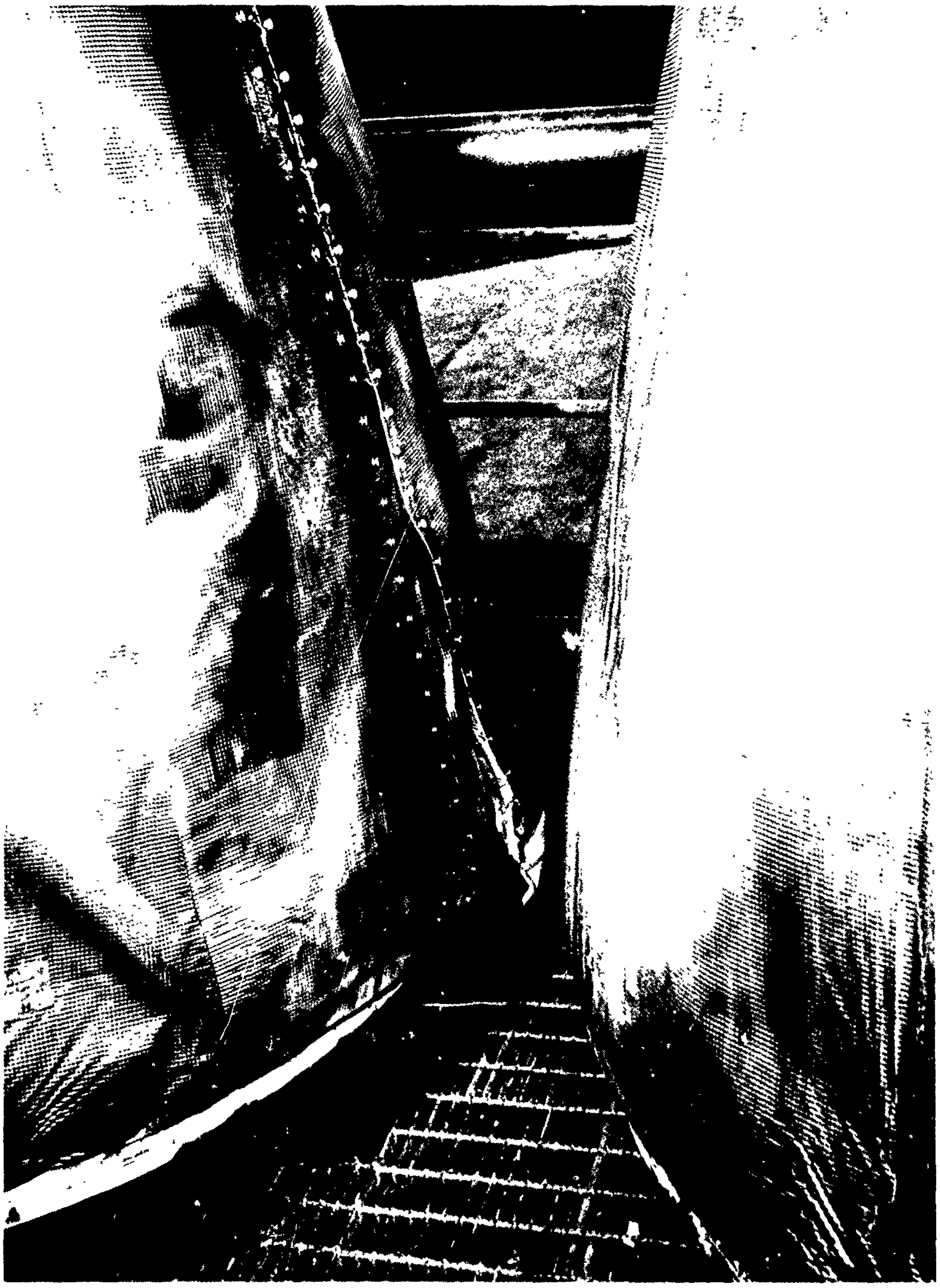


Figure 51 -- Refrasil Covers -- Modified Installation

3.2, Engine Components (cont.)

skirts. On Subassembly 1, the wire-lacing was similarily detached from four capstans on the same seam but below the chamber flange level.

The installation procedure prior to the test did not employ the Dacron cord prelacing. A Martin Company representative was present to observe.

Test No. -307, Engine S/N 15

Prior to this test, an exit closure expulsion test was conducted. The remaining attachment hardware from the expulsion test was left intact for the engine test. Except for the usual wire looseness, carbon deposits, stains and discolorations there were no discrepancies noted. All wiring and panels were intact.

Test No. -316, Engine S/N 15

A new set of Refrasil panels was installed on Subassembly 1 for this test; Subassembly 2 used panels from the previous tests. The panels were installed under the direction of a MMC-Denver representative. The Subassembly 1 panels were installed using Dacron cord lacing prior to applying the wire-loops and lacing in an effort to improve fit and alignment of the panels.

Postfire inspection disclosed the wire-lacing on the inner seam of Subassembly 2 was missing from the lower 14 pairs of capstans and the panel was bent outwards. (See Figure 51.) Review of motion pictures revealed the panel had sprung loose in the last ten seconds of the test. At that time, the lower areas of the inboard panels were glowing red from unusual combustion between the chambers, believed to be caused by leakage of fuel from above. Consequently, as the wire-loops and lacing burned away, restraint on the panels lessened and distortion resulted.

Table 29 -- Flight Instrumentation Components

COMPONENTS

Component Description	Vendor	Vendor Part Number Test Item	Vendor Part Number Production	Item SN	Numbers	Total No. Tests	Total Test Dur. Sec.	Test Parameter	Remarks
1. Resistance Temperature Transmitters Spec: AGC-42425									
a. 0-100°F	Rosemount	176AY	177HJ	3903	211,212, 213	3	240	1-TOS	
AGC PN 1153925-1	Rosemount	176AY	177HJ	3902	211,214, 215	3	420	1-TFS	
	CEC	4-550-0104	4-550-0104	3559	210,211, 212,213	4	440	2-TOS	
	CEC	4-550-0104	4-550-0104	3561	210,211	2	220	2-TFS	
b. 0-500°F	Rosemount	176AW	177HH	3896	211,214, 215	3	420	TopOi-B	
AGC PN 1153862-1	Rosemount	176AW	177HH	3896	214	1	200	TfpOi-B	
	CEC	4-550-0106	4-550-0106	3564	210,211	2	220	TfpOi-B	
2. Frequency-to-DC Converter Spec: AGC-42414 AGC PN 1153862	AGC	294232(MOD)	189411-5	0000060	209,210, 211,212 213	3 2	240 220	1-NT	Converter installed but not connected

*Test Nos.
Demo 14: 3051-D07-1A-2XX Demo 15: 3051-D07-1A-3XX

3.2, Engine Components (cont.)

3.2.5 Discharge Lines, P/N 1133568 (Oxidizer) and P/N 1133576 (Fuel)

The fuel and oxidizer discharge lines were redesigned to eliminate the problem of the ball and socket inserts becoming dislodged from the tripod. This is accomplished by making the ball and socket inserts an interference fit in the tripod. A leak detection land is provided at each seal groove to detect low pressure leakage.

Oxidizer lines, S/N 554 and S/N 555, and fuel lines, S/N 539 and S/N 542, installed on engine S/N 15, Subassemblies 1 and 2 respectively, accrued 2114 seconds total duration from 16 engine tests. Of these, ten tests were of 200 sec duration each

During the program there were no discrepancies or anomalies associated with any of the lines. Post-program examination found the lines free of distortion and suitable for reuse.

3.2.6 Flight Instrumentation

Temperature Transmitters

Resistance temperature transmitters, 0 to 100°F and 0 to 500°F units, manufactured by both Rosemount Engineering and Consolidated Electrodynamics Corporation were tested on engine S/N 14 as shown in Table 29. The test objective was to verify the compatibility of the redesigned unit with the engine operating environment.

Re-design of the transmitters was required for compatibility with the remote multiplexed instrumentation system (RMIS) used for flight. The redesigned units are practically identical to the previous P/N AS4011-100 and P/N AS4011-500 which they replace except for common-mode voltage and signal lead imbalance characteristics.

Table 30 -- Measurement Comparisons--Resistance Temperature Transmitters

Test Series 3051-007-1A-2XX

RTT Range °F	Serial Number	Test Number	Test Param.	Ref. Param.	Test(T) Avg °F	Ref(R) Avg °F	T-R °F	T-R % FS
0 - 100	3903	211	1-Tos	1-TosFM-A	62.11	60.37	1.74	1.74
		212	1-Tos	1-TosFM-B	91.051	90.236	+.815	+.8
		213	1-Tos	1-TosFM-B	68.53	65.86	+2.7	+2.7
0 - 100	3902	211	1-Tfs	1-TfsFM-A	61.4	53.4	7.4	+7.4
		214	1-Tfs	1-TfsFM-B	92.9	89.3	+3.6	+3.6
		215	1-Tfs	1-TfsFM-B	36.6	36.2	+0.4	+0.4
0 - 100	T3559	210	2-Tos	2-TosFM-A	40.69	40.44	+0.25	+0.25
		211	2-Tos	2-TosFM-A	62.43	60.48	+1.95	+1.95
		212	2-Tos	2-TosFM-B	91.02	90.42	+0.6	+0.6
		213	2-Tos	2-TosFM-B	68.88	65.88	+3.0	+3.0
0 - 100	T3561	210	2-Tfs	2-TfsFM-A	38.10	37.91	+0.19	+0.19
		211	2-Tfs	2-TfsFM-A	67.21	56.41	+10.80	+10.80
0 - 500	3896	211	TopOi-B	TopOi-A*	369.0	368.3	+0.7	+0.14
		214	TopOi-B	TopOi-A*	389.0	388.2	+0.8	+0.16
		215	TopOi-B	TopOi-A*	335.8	334.8	+1.0	+0.2
0 - 500	3897	214	TfpOi-B	TfpOi-A*	265.1	263.5	+1.5	+0.3
0 - 500	T3564	210	TfpOi-B	TfpOi-A*	333.0	289.0	+44.0	+8.7
		211	TfpOi-B	TfpOi-A*	327.7**	223.9	+103.8**	+20.8**

*Reference Measurements TopOi-A and TfpOi-A were Copper-Constantan Thermocouple Measurements.

**Data invalid, attributed to measuring system problem.

3.2, Engine Components (cont.)

Test data are summarized in Table 30 for each transmitter. All measurement data shown represent averages of 50 to 105 samples taken over a minimum sampling period of 5 seconds. As shown in the table the measurements obtained with the flight transmitters agreed within anticipated limits with the test stand reference measurements.

For the measurements T_{os} and T_{fs}, corresponding test stand measurements T_{os}FM and T_{fs}FM were used as references. The reference propellant suction temperature measurements were made with test stand resistance temperature transmitters located at the suction flowmeters, normally 25 to 50 ft upstream, so that propellant temperature differences were expected to exist between the flowmeter and the turbopump inlet suction speed locations. Table 30 shows representative temperature differences expressed in degrees and as a percentage of full scale transmitter range. Because of the physical separation of the test and reference measurement locations, the test data should not be construed as constituting calibration data.

Measurements of parameters T_{op0i} and T_{fp0i} by the 0-500°F units were referenced to redundant thermocouple measurements at the nearby locations. The measurement of T_{fp0i}-B, Test No. -211 was invalidated by an amplifier malfunction in the digital data system.

Based upon their performance during the engine tests, all resistance temperature transmitters are considered suitable for flight usage.

Three single-axis accelerometers were installed adjacent to the T_{os} and T_{fs} temperature transmitter bosses on the suction spools for several engine test runs. Figure 52 and Figure 53 are composite plots of the power spectral density computed for each axis at the T_{os} and T_{fs} locations, respectively. The vibration profile for the T_{os} location is based on data

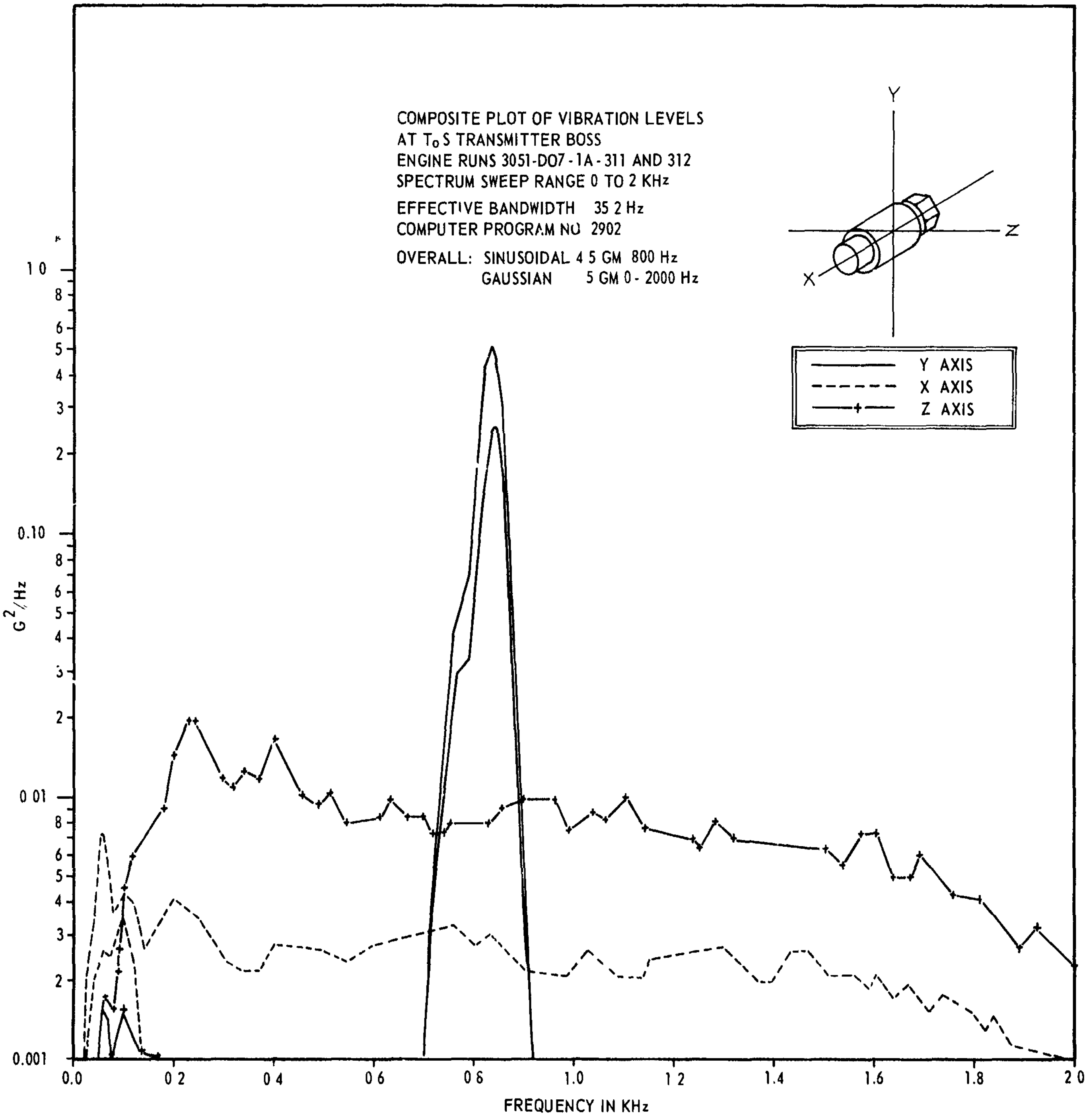


Figure 52 -- Vibration Levels, Tos Transmitter Boss

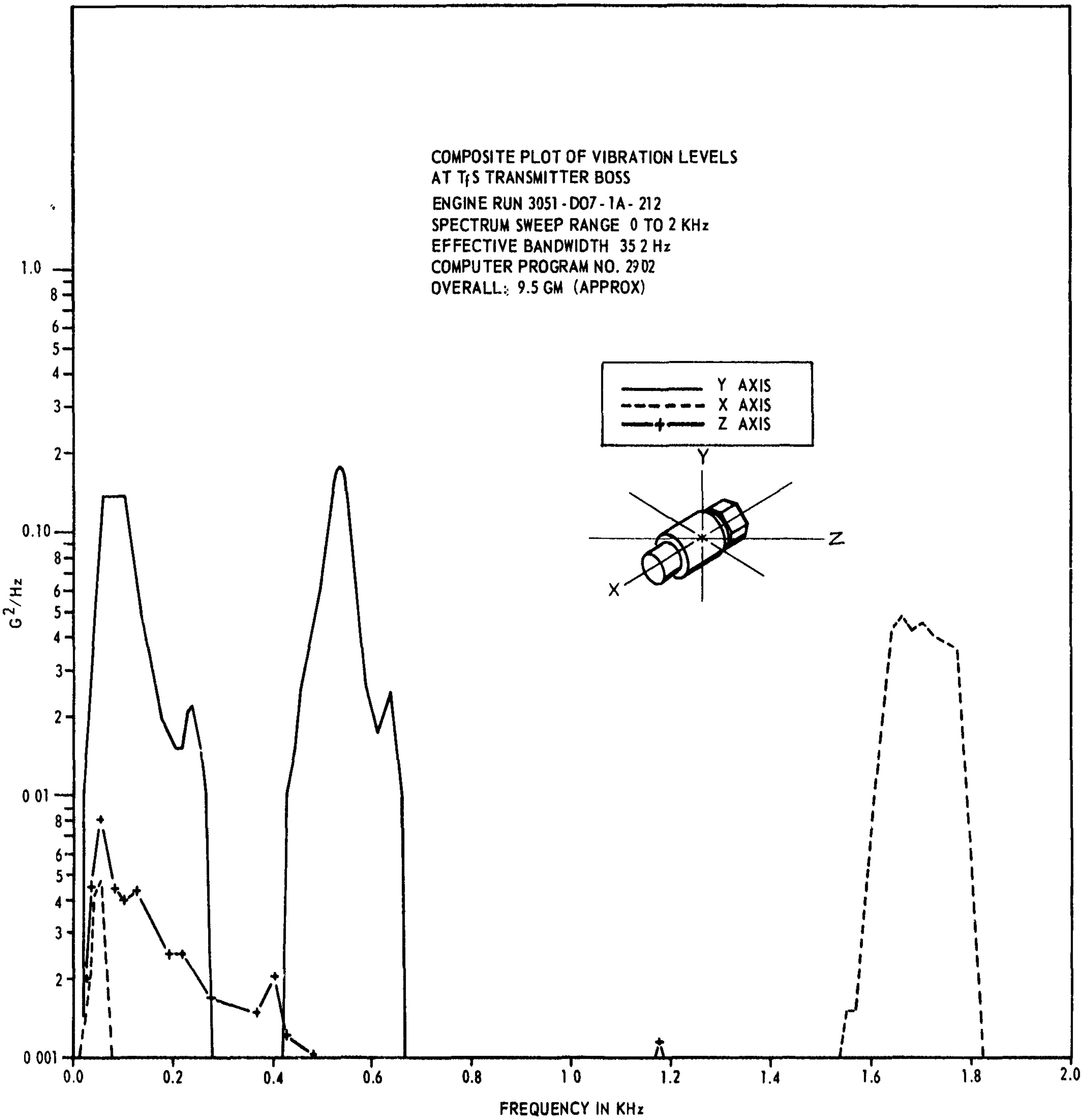


Figure 53 -- Vibration Levels, T_{fs} Transmitter Boss

3.2, Engine Components (cont.)

from two engine tests. The spectrum is defined as approximately 5g rms, 0 - 2000 Hz Gaussian in combination with a discrete sinusoidal level of 4.5g rms at 800 Hz. The profile for T_{fs} is based on data from one test and shows a spotty energy distribution of significance in the X and Y axis only. The overall 9.5g rms of Figure 53 is the resultant sum of the X and Y axis levels.

Both Figures 52 and 53 indicate vibration levels of less than one-half the acceptance vibration levels for the temperature transmitters (approximately 22g rms, combined sinusoidal and random).

Frequency-to-DC Converter, P/N 1153962

One frequency-to-dc converter, (P/N 294232 modified to a prototype T-IIIM configuration) was subjected to a total of five engine tests. The converter was fully operational during two tests for a cumulative operating duration of 220 seconds.

Modification of the converter, which consisted of the addition of a filter to attenuate impulse noise generated by the internal power supply, was required to make the unit suitable for use with the remote multiplexed instrumentation system (RMIS) during flight.

The dual test objectives were (a) to prove that the modified unit would withstand the engine operating environment, and (b) to evaluate the influence of the modification upon converter performance.

The modified converter was attached to the underside of the engine frame main strut, Quad III, to simulate the flight mounting configuration. After subjecting the converter to the engine environment for three tests, the converter was actuated for two additional tests. Converter signal input was

3.2, Engine Components (cont.)

obtained from the turbine speed probe of Subassembly 1, which was also connected to the input of the test stand turbine speed measuring system. Output signals from the converter were recorded on the digital system and on an oscillograph.

Examination of the oscillograph data revealed that the output noise had been eliminated by the modification. Comparison of the digitized data from the converter with the normal test stand data indicated an average error of +0.04 percent for the 200 second test (No. -212). Data averaged over shorter summary periods (from 2 to 10 seconds duration) showed agreements to better than 0.1 percent.

Based upon test results, the modified Frequency-to-DC Converter, P/N 1153962, is considered suitable for flight use.

P_c5 Pressure Transmitter Installation

The addition of a redundant thrust chamber pressure switch (TCPS) also required the addition of a tee to provide access to the thrust chamber combustion pressure for the flight instrumentation parameter P_c. This change in impulse tube configuration to the flight instrumentation was evaluated through the use of standard test transmitters on engine S/N 14.

No detrimental effects were noted due to the longer impulse tube and the parallel circuits of the TCPS.

3, Data and Component Evaluations (cont.)

3.3 THRUST CHAMBER ASSEMBLY COMPONENTS

3.3.1 Injector, PN 1130409-129

The injector contains distinct changes relative to previous Titan systems. These changes are as follows:

(a) A basic quadlet injection element rather than a like-on-like doublet.

(b) Increased injection orifice diameter corresponding to a 450 lb/element rating.

(c) Increased fuel injection velocity.

(d) The addition of a baffle system of seven, flush, radial blades that are internally cooled by oxidizer and externally cooled by fuel film cooling. The oxidizer coolant passing through the baffles is ejected from orifices at the tip of the trailing edge.

(e) A pie-shaped fuel manifolding system using seven pies rather than six, and aligned with the baffles.

(f) A reduced amount of chamber fuel film cooling to 10.5% of the total fuel.

These changes were made to improve the injector performance capability and achieve dynamically stable operation.

The four injector units used for the engine demonstration program all performed satisfactorily. At the conclusion of the program the injectors were

3.3, Thrust Chamber Assembly Components (cont.)

still fireable. The injector faces were marked extensively as expected, with some "checking" and surface cracking noticeable on the hottest surface areas. Some bell-mouthing of the orifices was noted; however, this is considered normal.

The baffles sustained base weld cracking throughout the test series. The majority of the cracks was attributed to poor quality welds due to improper weld preparations. The cracks were repaired several times between tests and, generally, the repaired areas did not have a tendency to incur cracks a second time. At no time during the test program could an effect adverse to engine operation be detected or associated with the baffle cracks. Injector performance was sustained and no thermal damage developed. In two instances, after 1900 seconds of test, a baffle tip developed a slot as the small lands between the tip orifices broke away. The slots were about one inch long and were caused by carburization and thermal cycling of the CRES 347 tip material. No adverse effect could be associated with the slots.

The injector clevis arms were strengthened and the yaw clevis was lengthened to provide clearance for the gimbal actuators around the redesigned larger oxidizer inlet elbow. No damage or wear was detected at the clevis attachments.

3.3.2 Raco Seals

The Teflon jacket on the standard inner Raco seal between the injector and the combustion chamber burns through the inner side either during or shortly after static test firing. The burnthrough provides a fuel leak path into the chamber through the perforations in the metal spring. The fuel leaking into the combustion chamber could potentially cause a decrease in the performance characteristics of the thrust chamber assembly. To minimize performance loss because of leakage through the perforated spring, it became

3.3, Thrust Chamber Assembly Components (cont.)

standard operating procedure to replace the Raco seal before each static test firing.

Postfire visual inspection of the inner Raco seals indicated that there was no Teflon damage where the Teflon jacket was in contact with the metal spring and the injector and chamber sealing surfaces.

Since the primary leak path is through the spring perforations, the recommendation was made to acquire Raco seals without perforated springs. Raco seals P/N 10050-21.776A were obtained. The springs in the seals were solid (had no perforations), were of the same material and thickness as the standard springs. The spring rate of the solid spring was calculated to be 1.5 times higher than the spring rate of the perforated spring.

Two solid spring inner Raco seals were tested with Engine S/N 15 as indicated:

Seal SN	Test No.	Duration, sec
1 & 2	3051-D07-1A-308	20.994
1 & 2	3051-D07-1A-310	200.361

The conditions of the Teflon jackets were as follows:

Seal No. 1 - The inner edge was burned through. The sealing surfaces were damaged for a length of approximately 5 in. in which the Teflon jacket was extruded toward the inner edge and caused the Teflon sealing surfaces to be missing from both sides.

Seal No. 2 - The inner edge was burned through. The sealing surfaces were damaged in four places in varying lengths (approximately 2, 4, 6, and 13 in.) in which the Teflon jacket had slid to one side, causing the sealing surface on the opposite side to be missing.

3.3, Thrust Chamber Assembly Components (cont.)

The solid spring in the Raco seal had a tendency to warp during spring fabrication. This solid spring warpage contributes to the Teflon jacket sliding to one side during installation, thus providing incomplete sealing contact. The spring rate on the solid spring is 1.502 times (approximately 50%) higher than the perforated spring rate and could cause the Teflon jacket to be cut along the outer edge of the solid spring. The assumption was verified by the two solid spring Raco seals which were test fired.

The recommendation to use the solid spring Raco seal, as currently manufactured, is not justified because of the tendency of the Teflon jacket to slip unseen during assembly and the cutting effects caused by the high spring rate.

3.3.3 Combustion Chamber, P/N 1130174

The combustion chamber incorporates significant improvements over the former 8:1 chambers used on other Titan systems. The specific improvements are as follows:

(a) A reduction of the exit area ratio to 6:1 to eliminate the need for a tube bifurcation.

(b) A reduction in the number of chamber tubes to 128.

(c) A change to a double-taper, round tube for minimum pressure drop and a uniform axial thermal profile.

(d) An improved forward flange to provide uniform flow distribution to the coolant tubes.

3.3, Thrust Chamber Assembly Components (cont.)

(e) An altered aft flange that reduces the coolant turning loss (down tube-to-up tube) and provides a sound structural interface for the 15:1 ablative skirt.

(f) The addition of a cylindrical support shell that is attached externally to the forward flange and extends to the expanded nozzle at the 2.2:1 area ratio for added structural support.

These improvements were made to provide the chambers with greater cooling capacity and structural strength. The increased cooling capacity was achieved through the reduction of the number of coolant tubes, the use of round tubes and the reduction in the area ratio of the cooled section aft of the nozzle. (The characteristic of this chamber configuration is that no location along the chamber length operates at a distinctly and significantly narrower burnout margin than at any other location). As a whole, the combustion chamber section (injector face to throat) is the area at which burnout would be likely if there were a serious disruption of the fuel film cooling. Should obstruction of fuel flow through a coolant tube occur, burnout would be expected to occur in the expansion nozzle. There were no burnouts experienced during the demonstration test series.

The structural improvement was accomplished by attaching a 0.109-inch thick cylindrical shell between the forward flange and a ring at the 2.2:1 area ratio diameter. The shell carries the high side and thrust loads caused by the 15:1 ablative skirt attachment and transmits these loads to the forward flange. Thus the loads are not transmitted by the coolant tubes through the critical throat section.

The combustion chambers used during the demonstration test program incurred only normal wear with little damage. The normal appearance of the chambers included blackened coolant tubes, minor fuel leakage at the forward

3.3, Thrust Chamber Assembly Components (cont.)

flanges (at the tube joints), slightly distorted forward flanges that resulted in chamber-to-injector gaps up to 0.035 in., cracks in the shell-to-chamber welds at the lower attachment, cracks and flaking of the epoxy coating, minor erosion on the forward flanges, and general discoloration. Damages other than normal that were noted, consisted of one instance of loose wirewrap, one instance of forward flange cracking and two instances of tube cracking.

The loose wire wrap was attributed to an improper application and use of unclean wire both above and below the throat sections. The wire wrap above the throat was replaced and remained intact during test, but the aft section loosened.

Cracking in the forward flange was caused by an in-process rework operation that had contaminated the weld joint between the closing band (P/N 1154237) and the flange (P/N 1154236) with braze alloy. The contamination induced brittleness of the material which produced cracking under thermal stress conditions.

The tube cracks were both caused by the deposition of molten metal from erosions in the forward flanges. The deposition of the metal on the tubes attacked the tubes metallurgically causing extensive carburization and unusual thermal loads.

3.3.4 Forged Dome, P/N 1155273

The forged dome design represents a cost savings improvement over the welded configuration and also provides a configuration more repeatable from part-to-part due to the elimination of the numerous major weld operations. The one piece forged dome is inherently stronger than the welded dome.

3.3, Thrust Chamber Assembly Components (cont.)

No malfunctions or discrepancies occurred on the domes during the demonstration test program and all four units are still serviceable. Dome assemblies S/N 523 and S/N 522 were tested on Engine S/N 14 for an accumulated duration of 1845 seconds. Assemblies S/N 004 and S/N 002 were tested on engine S/N 15 for an accumulated duration of 2115 seconds.

3.3.5 Oxidizer Inlet Elbow, P/N 1131576

The Stage I oxidizer inlet elbow was redesigned for the Titan IIIM engine in order to eliminate turning vanes. This redesign was necessary to eliminate vane cracks which plagued the earlier Titan systems. Since turning vanes had been inserted in the first place to decrease the pressure drop around sharp turns, the entire inlet elbow was changed to provide maximum bend radii and minimum pressure drop.

Four elbows of this configuration were fabricated for use with the two demonstration engines. Elbows S/N 003 and S/N 007 were installed on engine S/N 14 and were tested for an accumulated duration of 1844.9 sec while undergoing 15 test cycles. Elbows S/N 005 and S/N 006 were installed on engine S/N 15 and were tested for an accumulated duration of 2114.7 sec while undergoing 16 test cycles. No test anomalies relating to the inlet elbows were experienced.

Following the demonstration test series, each elbow was inspected for damage and condition. No distortion or other damage was found and all of the elbows were considered satisfactory for retesting.

3.3.6 Gimbal Assembly, P/N 1129532

The Stage I gimbal was redesigned to withstand the higher thrust and tensile loads predicted for the Titan IIIM engine system. Bearing race

3.3, Thrust Chamber Assembly Components (cont.)

fabrication procedures were changed to provide a uniform race hardness and to prevent race brinelling at the 411,000 pound maximum predicted subassembly thrust. A housing redesign was incorporated to withstand an ultimate tensile load of 56,000 pounds. This design change increased the mounting flange thickness from 0.437 inches to 0.500 inches and altered the undercut section from triangular to a circular segment. The aluminum component heat treatment was also changed from 7075-T-6 to 7075-T-73 to decrease susceptibility to stress corrosion cracking.

Four gimbal assemblies were fabricated for the demonstration test series. Gimbal assemblies S/N 002 and S/N 003 were installed on engine S/N 14 for an accumulated test duration of 1844.9 sec while undergoing 15 test cycles. The engine was gimballed during two of the 15 tests for an accumulated duration of 34.2 sec. Gimbal assemblies S/N 001 and S/N 004 were installed on engine S/N 15 and accumulated 2114.7 sec during 16 test cycles. Gimballing was conducted on three tests for an accumulated time of 96.6 sec. Both engine assemblies were equipped with ablative nozzle extensions and Refrasil Insulation panels for the gimbal tests.

Gimballing was conducted at a rate of 0.5 cps with a total travel of $\pm 6°$ in both the pitch and yaw planes. No test anomalies relating to the gimbal assemblies were experienced.

Following the demonstration test series, each gimbal was inspected for damage and/or condition. All assemblies were found to contain from one to five broken bearing spacers. There was no damage inflicted by the broken spacers.

3, Data and Components Evaluation (cont.)

3.4 TURBOPUMP ASSEMBLY COMPONENTS

3.4.1 High-Speed Shaft and Bearings

Both turbopump gearboxes used with the demonstration engines incorporated the redesigned shaft and bearing installations. There were no operational discrepancies encountered during the test program.

The high-speed shaft has been redesigned to a greater diameter to improve stiffness so that the shaft critical speed is above the operational speed. The former lower ball bearing (B-6) was replaced with a roller bearing with a larger bore to improve the capability for supporting radial loads. The shaft/rotor coupling was changed from a dog/slot design to the curvic coupling design. A supplementary benefit of the shaft and bearing redesign is that the shaft can be removed from the gearbox for inspection without disturbing the bearing press-fit.

A review of the high-speed bearing temperatures from the 200 sec tests indicates that bearing operation was satisfactory. The maximum bearing temperatures recorded were:

Table 31--High Speed Bearing Temperatures -- Maxima

Engine S/N 14

	TPA SN 008	TPA SN 006	Maximum Allowable
Upper Bearing (B-4)	208	219	300
Center Bearing (B-5)	253	260	350
Lower Bearing (B-6)	318	330	360

3.4, Turbopump Assembly Components (cont.)

Table 31--High Speed Bearing Temperature (cont.)

Engine S/N 15

	TPA SN 009	TPA SN 011	Maximum Allowable
Upper Bearing (B-4)	196	203	300
Center Bearing (B-5)	244	245	350
Lower Bearing (B-6)	340	322	360

3.4.2 Gearbox and Lubrication

The gearbox data were reviewed to evaluate the lube system changes. The parameters analyzed for this evaluation were the gearbox bearing temperatures (with the exception of the high-speed bearings), the lube supply pressure, and the lube filter pressure drop. The high-speed bearing temperatures are discussed in the preceding paragraph.

The maximum bearing temperatures at the end of 200 sec are as follows:

Table 32--Gearbox Bearing Temperatures

Engine S/N 14

	SA 1 TPA 008	SA 2 TPA 006	Maximum Allowable
B1 (Upper Oxidizer Bearing)	168	154	200
B2 (Center Oxidizer Bearing)	179	191	260
B3 (Lower Oxidizer Bearing)	212	223	270
B7 (Upper Idler Bearing)	204	220	260
B8 (Lower Idler Bearing)	209	211	290
B9 (Upper Fuel Bearing)	165	168	200
B10 (Center Fuel Bearing)	190	203	250
B11 (Lower Fuel Bearing)	200	208	260

3.4, Turbopump Assembly Components (cont.)

Table 32—Gearbox Bearing Temperatures (cont.)

Engine S/N 15

	SA 1 TPA 009	SA 2 TPA 011	*Maximum Allowable
B1 (Upper Oxidizer Bearing)	152	152	200
B2 (Center Oxidizer Bearing)	175	169	260
B3 (Lower Oxidizer Bearing)	209	210	270
B7 (Upper Idler Bearing)	198	200	260
B8 (Lower Idler Bearing)	198	210	290
B9 (Upper Fuel Bearing)	159	156	200
B10 (Center Fuel Bearing)	213	180	250
B11 (Lower Fuel Bearing)	184	194	260

* The maximum allowable bearing temperature listed in Column 3 is in accordance with the System Test Implementation Plan, SSD-CR-65-8180-140, Revision 2, 17 March 1967.

All bearing temperatures were well below the maximum specified in the System Test Implementation Plan.

The parameter which reflects the flow of lube to the gearbox lube jets and oilers is the pressure rise across the lube pump, ΔPLP. The lowest pressure rise at 200 sec duration for the engine S/N 14 tests was 38 and 31 psi on TPA's S/N 008 and S/N 006 respectively. The lowest pressure rise for the engine S/N 15 test was 30 and 34 psi for turbopumps S/N 009 and S/N 011 respectively.

Even these lowest pressures compare very favorably to the nominal pressure of the gearbox prior to the lube system redesign. The average lube pump pressure rise at 200 sec of 51 acceptance tests of turbopumps of the previous design was 17.5 psi. Seven of these 51 tests ended with lube pressure

3.4, Turbopump Assembly Components (cont.)

rise of less than 5 psi. The primary reason for the increased pressure of the Titan IIIM gearbox is the larger capacity lube pump, 5.2 gpm vs 3.5 gpm of the previous design.

The fact that the lube pressure of the Titan IIIM gearbox is steady with no erratic drop indicates that the overall lube system is performing satisfactorily with no detrimental churning or flooding of lube oil in the gearbox. This condition reflects the improvements in the scavenging or return of lube from the gearbox interior to the reservoir.

The highest pressure drop measured across the lube oil cartridge filters during engine S/N 14 tests was 1.6 and 4.0 psi on turbopumps S/N 008 and S/N 006 respectively. The highest pressure drop measured on engine S/N 15 tests was 3.8 and 1.6 psi on turbopumps S/N 009 and S/N 011, respectively. The lube oil bypass relief valve is set at a minimum pressure drop of 42 psi, which means that lube oil will not bypass the filter until a pressure drop of at least 42 psi is reached. The low pressure drop across the filter indicates that the filter has ample area and is not susceptible to plugging under normal conditions.

3.4.3 Turbine First-Stage Rotor

The first-stage rotor of the brazed fir tree cast blade configuration was replaced with the one-piece fabricated rotor (PN 115490). The reason for the redesign was to eliminate turbine failures which had resulted from loss of a cast rotor blade. The redesigned rotor has 83 blades which are integrally machined from a Waspalloy forging. The blades are hollow with the radially oriented hole starting from the blade tip and extending to a point just below the base of the blade. The purpose of the hole is twofold:

3.4, Turbopump Assembly Components (cont.)

(a) To maintain the moment of inertia of the rotor so that the shaft dynamics are not affected.

(b) To produce a junction at the base of the blade which had a gradual change in cross-section. This is necessary to reduce the thermal shock during the start and shutdown transients, and thus minimize thermal stresses.

The rotor also features radially oriented key-hole slots between the blades. The length of the slots has been proportioned so that the resulting natural frequency of the blade is outside the dominant driving frequency within the turbopump (12,400 cps). The use of generous radii at the base of the blades produces a junction which is low in stress concentration and is high in resistances to thermal shock. The balance rim and the remaining portions of the rotor below the balance rim are dimensionally similar to the Titan II rotor.

Three of the redesigned rotors were tested on engine S/N 15 with no operational discrepancies. Although the performance of the 83-blade rotors was lower than that of the 112-blade rotor, engine balances and objectives were achieved.

The rotors used with engine S/N 14 were as follows:

Tests	Rotor S/N	TPA S/N	Accumulative Time, sec
205-215	006	008	1308.5
205-	004	006	1510.6*

*Includes 1 TPA cold-flow test

3.4, Turbopump Assembly Components (cont.)

The rotors used with the engine S/N 15 tests were as follows:

Tests	Rotor S/N	TPA S/N	Cumulative Time, sec
301-310	001	009	1448.6
311-316	783	009	666.1
301-316	759	011	2114.7

3, Data and Component Evaluations (cont.)

3.5 ENGINE CONTROLS

3.5.1 Thrust Chamber Oxidizer Valve, P/N 1130063-19

A program was initiated in order to achieve solutions to the contamination within the valve bearing cavities in the form of salts caused by inadequate cleaning and the extrusion of the bearing liner experienced with previous Titan II configuration thrust chamber valves (TCOV).

The Stage I thrust chamber oxidizer valve incorporates the AEIP bearing cleaning ports and a reversed direction gate rotation of approximately 90° full open. Actuation is produced by a clockwise arm motion parallel to that of the actuation arm of the thrust chamber fuel valve by means of a lengthened turnbuckle assembly. This is distinguishable from the Titan II cross link (opposite rotating) non-parallel arm gate movement of approximately 78° full open counterclockwise.

The bearing cavity is accessible to postfire cleanout, neutralization, flushing and purging by means of two ports with removable plugs in each bearing retainer end cap. For a properly assembled TCOV the oxidizer can flow from the gate side along the shaft bearings to the bearing cavities in the outboard ends. Sealing of the bearing cavity is accomplished by means of a crush washer deformed on loading by serrations in the body and retainer end cap. Sealing of the shaft is by means of dynamic type omniseals in the outboard ends of the bearings. The Titan II configuration omniseals have been removed from the gate/bearing position. A redesign of the actuator arm was required to accommodate the reverse gate rotation geometry. Relocated flats on the shaft to match the orientation of the arm were incorporated. Modifications to the AEIP bearing retainers were included to remove the overtravel stop which is not required by the clockwise rotation configuration. Reduction in the period of application of peak proof pressure was incorporated into the valve acceptance test program to reduce bearing liner extrusion.

3.5, Engine Controls (cont.)

This valve functioned satisfactorily throughout the engine demonstration firing. Planned postfire cleaning operations at the end level involved neutralizing, flushing, and purging with gaseous nitrogen through the main valve cavity, past the lipseal, and through the bearing cavities by way of the ports in the bearing retainer caps. Review of the detail hardware on post test disassembly revealed the following minor discrepancies:

The anodize on the large bores in the valve body was eroded during firing. On one Kel-F lipseal there was the appearance of a hairline stress crack in line with the chamfered edge of the lipseal retainer ring. A slight quantity of white salt was found in the bearings. Very slight bearing liner extrusion was observed at one bearing. The liner on one of the bearings was found folded in upon itself, possibly caused by peeling of the Armalon surfaces prior to buildup, which resulted in fold over of the liner when the shaft was inserted. One bearing retainer had a small quantity of a brown foreign material in the inner bore. Some white salty powder was observed in the cavity and on the omniseals. Evidence of galling on the inboard bearing end matched by slight galling of one gate end was noted.

It is considered that these valves withstood the engine demonstration firings satisfactorily and could be reused after cleaning and replacement of soft goods and bearings.

3.5.2 Thrust Chamber Fuel Valve, P/N 1130064-9

The Stage I thrust chamber fuel valve (TCFV) incorporates a polypropylene lipseal in the actuator bore and a polypropylene microseal on the piston shaft to reduce the sensitivity of the lipseal to high temperature and the galling of the actuator piston. Operation of engine S/N 15 was satisfactory with no anomalies. Post fire disassembly of these valves after the demonstration tests revealed that except for slight hairline scratches on the long shaft,

3.5, Engine Controls (cont.)

the pistons appeared to be in good condition with no appreciable evidence of galling. The shafts were undamaged; however, a brown viscous deposit was found on the stepped end of the actuator. Analysis of the contaminant showed "rust" (iron oxide) from the cleaning water system suspended in the DC-11 lubricant. Salt crystals and a black grease-like deposit were noted on the small bore in the actuator body outside the piston housing. Samples were taken for analysis and determined to be carbon black from the O-rings and silicone from the DC-11 lubricant.

The bearing liners were found slightly (approximately 0.050 in.) extended, with galling on the inboard ends adjacent to the gate. Salt crystals were found on both sides of the piston retainers and the previously noted black gummy deposit was found at the small bore.

The sealing surface of the gates were in good condition. Slight evidence of galling was noted at the gate ends. The lipseals were found intact, with no visible damage.

Some salt crystals were found in the main bores in the body. Dirt was noted on the bearing retainer caps and the O-ring grooves contained some of the black gummy material (deteriorated O-rings).

It is considered that the design of the TCFV's is adequate as evidenced by the engine demonstration firings.

3.5.3 Pressure Sequence Valve, P/N 1131736-9

The Titan IIIM pressure sequence valve (PSV) incorporates spring housings and quick disconnects made from stainless steel as opposed to the Titan II aluminum counterparts. With the exception of a solenoid malfunction discussed in Section 6.4, the PSV's functioned satisfactorily throughout the

3.5, Engine Controls (cont.)

demonstration firing program. Postfire disassembly of assemblies S/N 641, S/N 642, S/N 643 and S/N 644 disclosed the following hardware conditions:

Both spring housings, piston and sleeve assemblies and piston stops looked very clean with no evidence of corrosion or contamination.

One adapter plate had black O-ring stains in the O-ring groove, while the other plate had some salt crystals in this groove.

One solenoid core housing (external surfaces) was oxidized.

One body inlet had a small amount of black particles in the screen.

It is considered that the PSV's would have continued to function as required with very little cleanup prior to reassembly.

3.5.4 Redundant Thrust Chamber Pressure Switch, P/N 706472-19

The Titan IIIM system specification required a redundant indication of the thrust level as measured by chamber pressure. A redundant thrust chamber pressure switch (TCPS) was provided for each subassembly identical to the existing pressure switches but including separate pressure ports, wiring and interface. The Titan IIIM redundant TCPS's sustained 31 test firings and maintained the required "make" and "break" switch points at pressures (600/640 psia "make", deactuation pressure 5 to 50 psi below make pressure) within the specified tolerance. (See Table 33 for the record of the actual "make" and "break" switch points during the demonstration firings,

Table 33 -- Thrust Chamber Pressure Switch Data

Engine S/N 14

Test Number	S/A 1 TCPS B Make	S/A 1 TCPS B Break	S/A 1 TCPS C Make	S/A 1 TCPS C Break	S/A 2 TCPS B Make	S/A 2 TCPS B Break	S/A 2 TCPS C Make	S/A 2 TCPS C Break
3051-D07-1A-201	612	581	618	591	604	582	600	582
202	633	594	625	582	Inv	Inv	615	592
203	629	585	621	573	618	603	627	611
204	626	579	618	581	630	575	620	577
205	634	599	627	592	629	588	635	590
206	628	595	619	597	626	580	626	571
207	630	588	630	588	628	611	637	602
208	638	574	619	576	625	568	620	568
209	617	585	622	576	615	583	617	581
210	623	589	625	587	618	586	631	594
211	633	579	633	593	621	572	625	572
212	631	591	616	577	614	580	631	580
213	623	588	623	575	624	595	624	582
214	626	582	626	574	617	578	627	578
215	628	591	628	578	624	588	634	588

Engine Specifications: Make - 620 $\pm$ 40 psia

Break - 600 $\pm$ 60 psia

Table 33 -- Thrust Chamber Pressure Switch Data (cont.)

Engine S/N 15

Test Number	S/A 1 TCPS B Make	S/A 1 TCPS B Break	S/A 1 TCPS C Make	S/A 1 TCPS C Break	S/A 2 TCPS B Make	S/A 2 TCPS B Break	S/A 2 TCPS C Make	S/A 2 TCPS C Break
3051-D07-1A-301	605	566	598	598	605	559	604	573
302	618	578	617	580	613	576	613	575
303	626	575	617	579	618	575	627	578
304	631	577	613	581	617	574	617	582
305	626	584	611	584	628	578	628	601
306	628	580	619	580	626	580	617	588
307	625	580	617	583	619	582	623	582
308	618	593	618	593	631	590	N.A.	587
309	No Ign	No Ign	No Ign	No Ign	631	575	631	575
310	635	583	619	584	632	590	634	590
311	614	591	617	580	614	582	628	580
312	631	589	627	587	628	586	633	586
313	633	589	622	580	627	584	627	584
314	626	583	629	581	624	590	633	590
315	620	533	620	576	625	584	633	584
316	625	593	614	593	623	570	623	570

Engine Specification: Make - 620 $\pm$ 40 psia

Break - 600 $\pm$ 60 psia

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4. Evaluation of Auxillary Components

4.1 POGO Fuel Accumulators

4.2 Exit Closures

4.3 Ablative Skirt, 12:1 Area Ratio

4.4 Gimbal Actuators, 10-sq in.

4.5 Flight Instrumentation Pressure Transducers

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4. EVALUATION OF ANCILLARY COMPONENTS

4.1 POGO FUEL ACCUMULATOR PROGRAM (CO 125)

The objective of this program was to gain test experience on the engine-accumulator system and provide data to evaluate system response. The results of the analytical evaluation and specific data will be presented separately in a final program report to be presented in compliance with Change Order 125.

Martin supplied fuel accumulators were utilized on seven valid peripheral tests for a cumulative duration of 1405 seconds. Six of the tests used fuel prevalves in conjunction with the accumulators (see Figures 54 and 55). In addition, four short duration adjustment tests were conducted utilizing pre-valves only to serve for baseline data (see Table 34).

Special instrumentation was added to the standard instrumentation for these tests. Frequency sensing instrumentation (see Table 35 and Figure 56) was supplied for one peripheral and one adjustment test.

The serial numbers of accumulators and prevalves used are:

	S/A 1	S/A 2
Prevalves	1852	2000
Accumulators	101	130

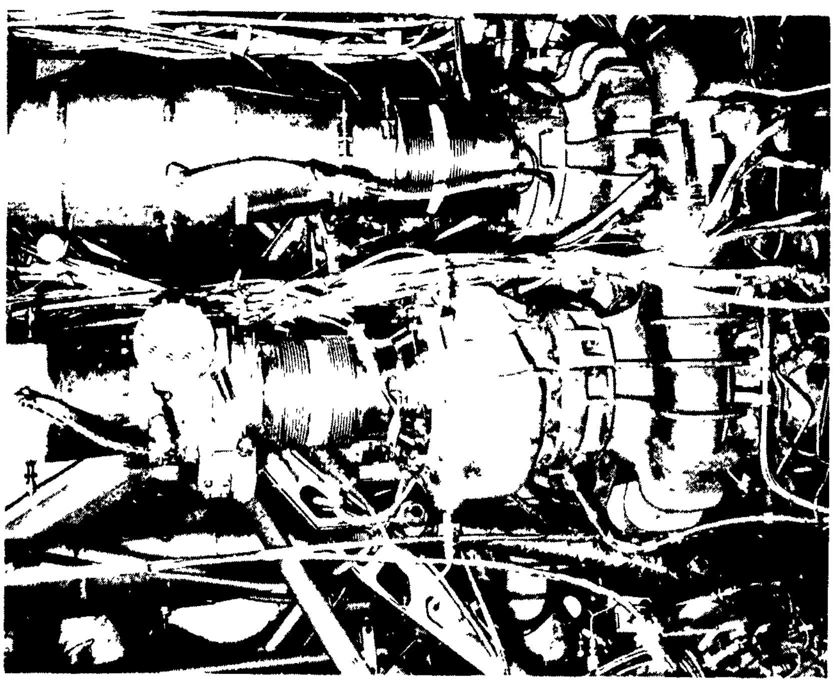

Figure 54 -- POGO Fuel Accumulator, S/A

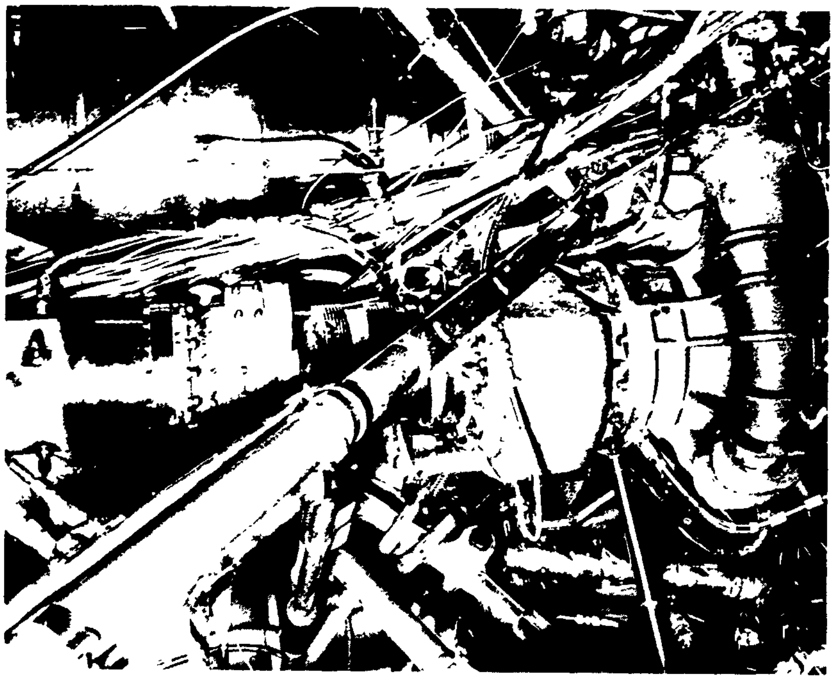

Figure 55 -- POGO Fuel Accumulator, S/A 2

Table 34 -- Demonstration Tests with POGO Configuration

Engine	Test No.	Duration	Prevalves	Accumulators
S/N 14	3051-D07-1A-210	200.315	-	x
	212	201.006	-	x
	215	200.458	x	x
S/N 15	308	20.977	x	-
	309*	Inv	x	x
	310	200.361	x	x
	311	21.340	x	-
	312	201.114	x	x
	313	20.845	x	-
	314	200.908	x	x
	315	21.095	x	-
	316	200.809	x	x

*Invalid Test θ Malfunction

Table 35 -- POGO Test Instrumentation

Functions	-210	-212	-215	-308	-309	-310	-311	-312	-313	-314	-315	-316
1-Pfs-41	x	x	x	x	x	x	x	x	x	x	x	x
2-Pfs-41	x	x	x	x	x	x	x	x	x	x	x	x
1-Pfs-9.5	-	-	-	-	-	-	-	-	(F)M-1	(F)M-1	-	-
2-Pfs-9.5	-	-	-	-	-	-	-	-	(F)M-1	(F)M-1	-	-
1-PgFTA	x	x	x	-	x	x	-	x	-	(F)M-1	-	x
2-PgFTA	x	x	x	-	x	x	-	x	-	(F)M-1	-	x
1-Pfs-1	x	x	x	-	x	x	-	x	-	(F)M-1	-	x
2-Pfs-1	x	x	x	-	x	x	-	x	-	(F)M-1	-	x
1-Pfd-6.5	-	-	-	-	-	-	-	-	(F)M-2	(F)M-2	-	-
2-Pfd-6.5	-	-	-	-	-	-	-	-	(F)M-2	(F)M-2	-	-
1-Pos-22	-	-	-	-	-	-	-	-	(F)M-1	(F)M-1	-	-
2-Pos-22				-	-	-	-	-	(F)M-1	(F)M-1	-	-
1-Pod-8.5	-	-	-	-	-	-	-	-	(F)M-2	(F)M-2	-	-
2-Pod-8.5	-	-	-	-	-	-	-	-	(F)M-2	(F)M-2	-	-
1-GFSL-1Y	-	-	-	-	-	-	-	-	R	R	-	-
1-GFSL-2X	-	-	-	-	-	-	-	-	R	R	-	-
1-GFSL-3Z	-	-	-	-	-	-	-	-	R	R	-	-
1-GFSL-4Y	-	-	-	-	-	-	-	-	R	R	-	-
1-GfTPAi-Y	-	-	-	-	-	-	-	-	R	R	-	-
2-GfTPAi-Y	-	-	-	-	-	-	-	-	-	R	-	-

x Standard instrumentation equipment
(F)M-1 Flush mount Microdots, 0 to 500 psia, 100 psi p-p.
(F)M-2 Flush mount Microdots, 0 to 2000 psia, 2000 psi p-p.
R Accelerometer Range 0 to 15 g's, 0-50 cps

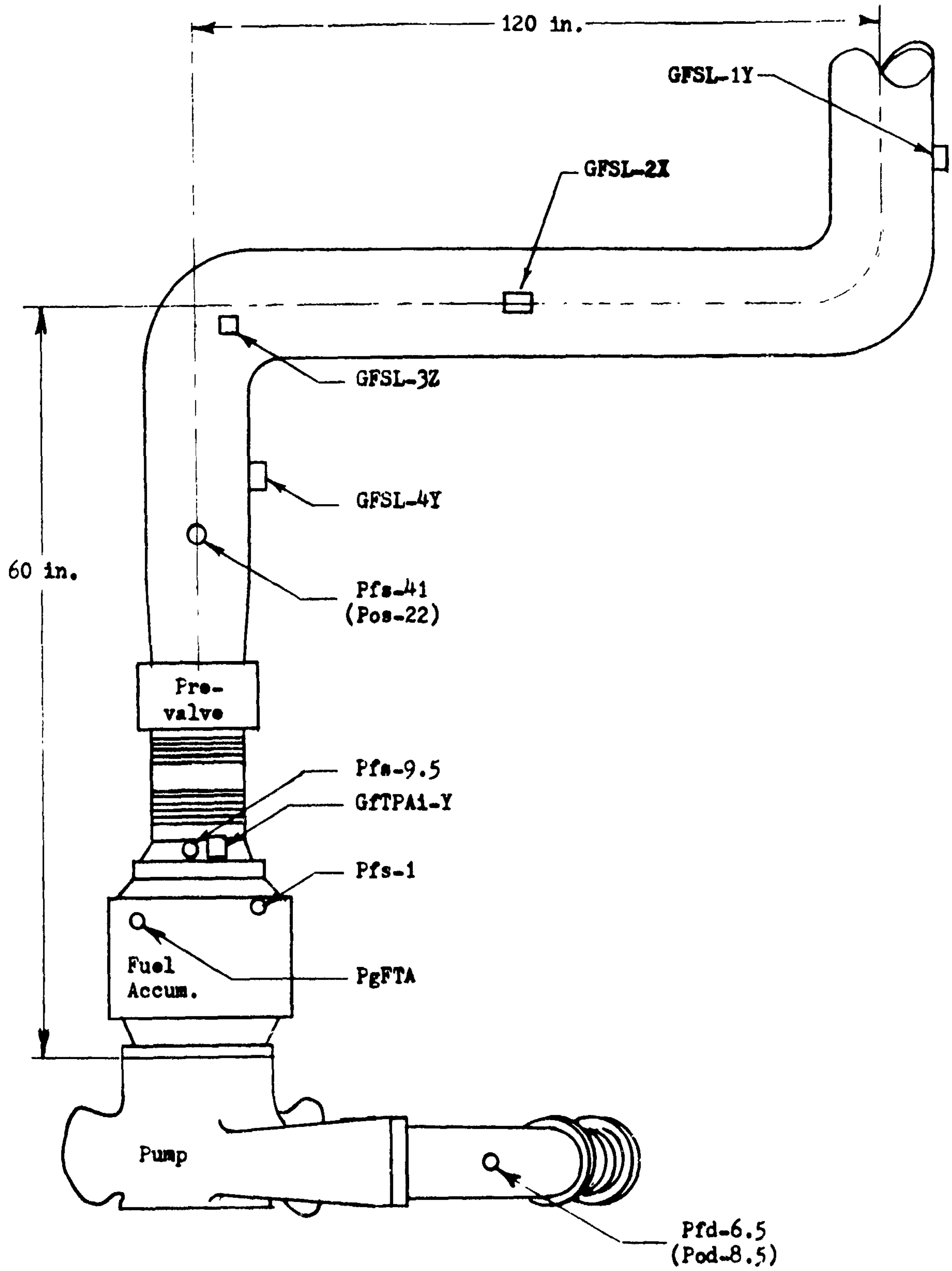

Figure 56 -- POGO Instrumentation Locations

4, Evaluation of Ancillary Components (cont.)

4.2 EXIT CLOSURES (CCN 44)

The objective of this program was (a) to evaluate the physical interface compatibility of the exit closure system with the engine (b) to evaluate functionally the integrated exit closure system, and (c) to verify the operational service procedures for exit closure flight preparation.

Exit closure expulsion tests with closures installed on both TCA nozzles were conducted with engine S/N 15 on two occasions prior to firing the engine. The closures were retrieved in netting attached to the test facility in an effort to preserve their condition for postfire examination.

To achieve simulation of staging without actual engine ignition, the thrust chambers were pressurized with GN_2 prior to detonating the ordnance in order to simulate the pressure representing the oxidizer lead vapor. The operation and recovery of the closures were successful.

4.2.1 Exit Closures--S/N 005 and S/N 006

The expulsion test (No. 3051-D08-1V-001) of these closures was completed successfully prior to engine Test No. 3051-D07-1A-307. The staging and separation of the closures were satisfactory and no damage was inflicted on the thrust chamber or accessories. The remaining hardware, still attached during the engine tests, was examined and found to be in good condition.

One significant problem was encountered during installation of the closures and necessitated an interface change. See Figure 57. The exit closure was designed to fit over the ablative skirt and MMC refrasil cover. The refrasil cover end was supposedly 0.015 in. thick; however, the effective thickness was greater because of spot welded ends, the end was wrinkled and

Figure 57 -- Refrasil Cover and Exit Closure.

Figure 58 -- Modification to Refrasil and Exit Closure

4.2, Exit Closures (CCN 44) (cont.)

would not fit between the skirt and closure. A change in The Martin Company-Aerojet interface is required to correct the situation. To facilitate this test, the refrasil panels were installed outside of the closure. Meanwhile an interface change was initiated to permit a satisfactory installation of the closure under the refrasil as shown in Figure 58. Drawing changes were made accordingly and final demonstration with the revised installation was accomplished immediately prior to Test No. -316.

4.2.2 Exit Closures--S/N 007 and S/N 008

The expulsion test (No. 3051-D08-1V-002) of these closures was completed successfully prior to engine Test No. 3051-D07-1A-316. Again, the staging and separation of the closures were satisfactory. The condition of the closures was good and no damage was inflicted on the thrust chamber or accessories.

Installation of the closures was performed using operating systems procedures. Only minor discrepancies were encountered and corrective action was taken. The discrepancies were as follows:

(1) CDF lines were slightly short, thereby affecting the securing and routing of the lines within the engine compartment. The drawings were changed to increase the length of the CDFs to correct this problem.

(2) Excessive field operations were required to wrap the CDF lines with insulation tape and to bond pieces of cork insulation to the interface brackets. Drawings were changed to accomplish these operations prior to shipping.

Following the engine test, an examination of the closure hardware disclosed erosion on the thin aluminum attaching flange of both closures at the

4.2, Exit Closures (CCN 44) (cont.)

inboard (between thrust chambers) locations. This was attributed to unusual combustion presumably from a fuel seal leak located above. The leakage and combustion were verified by subsequent motion picture review and postfire inspections. This condition in no way affects the exit closure system.

4, Evaluation of Ancillary Components (cont.)

4.3 ABLATIVE SKIRT (12:1)

4.3.1 Ablative Skirts S/N 003 and S/N 005 (P/N 1155707-1)

Two 12:1 ablative skirts, S/N 003 and S/N 005 were fired for 201.006 sec on the Titan IIIM Demonstration Test No. -214. The 15:1 Refrasil insulation panels were truncated to fit the shorter 12:1 configuration for this test.

The 12:1 ablative liner wall was designed to obtain a backwall temperature at the end of 180 sec static testing comparable to that obtained by the 15:1 design at 200 sec. The average 15:1 temperature after 200 sec is approximately 305°. The maximum operating temperature is set by specification at 250°F.

Backwall temperatures at two locations and outer laminate skin temperature at one point were measured on each subassembly. The temperatures measured at 180 sec were as follows:

Table 36--Ablative Skirt Test Temperatures at 180 Seconds

Measured Test Parameter	Temperature °F S/N 003	Temperature °F S/N 005
Liner backwall, TAS-1	313	--
Liner backwall, TAS-2	312	260*
Outer laminate, TAS-4	124	130

*Discrepant TC

All temperatures presented above indicate satisfactory performance in accordance with the design limits set.

Test No. 3051-D07-1A-214

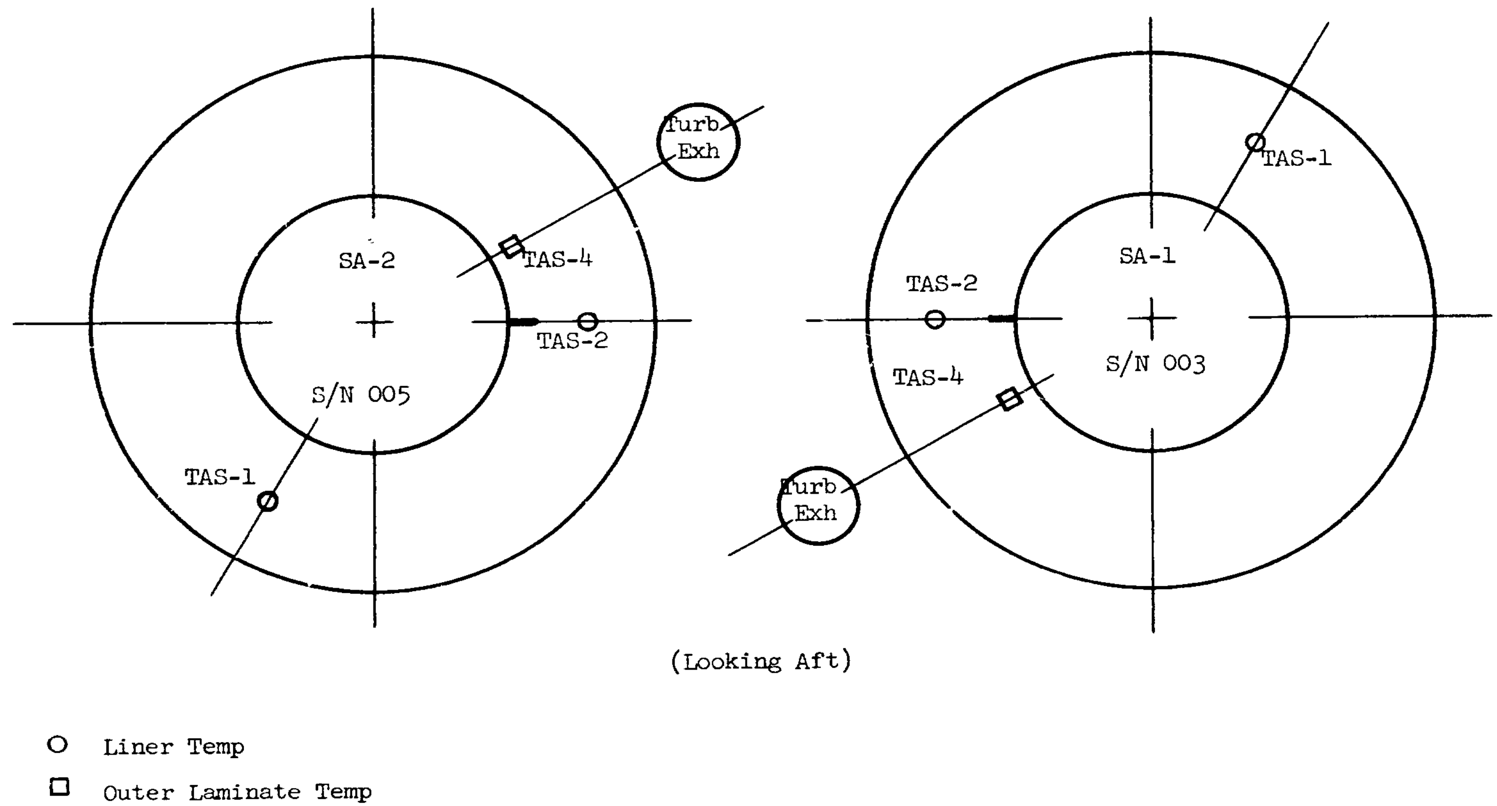

Figure 59 -- 12:1 Ablative Skirt Instrumentation Locations

4.3, Ablative Skirt (12:1) (cont.)

The location of the thermocouples is shown in Figure 59. The temperature plots obtained for skirts S/N 003 and S/N 005 are presented in Figures 60 and 61, respectively.

Although the two skirts performed satisfactorily, as indicated, both units were severely damaged by postfire burning which became most pronounced, producing the severest temperatures (1600°F-1700°F), atFS2 + 900 sec on Subassembly 2 and at FS2 + 1300 sec on Subassembly 1. The area of greatest damage was sustained at the point located under the turbine exhaust stacks. In these areas the resin was completely removed with no ash remaining, indicating that the necessary oxygen to produce this result was available. Pictures of the damaged units are presented in Figure 62. Figure 63 shows the skirts (postfire) mounted on the engine, including the refrasil covers. Figure 62 is an enlargement of the damaged area on both skirts, while views 62b and 62c show the details of the fire damage to skirts S/N 003 and S/N 005, respectively.

Thermal decomposition of a phenolic resin system begins at approximately 800°F. Epoxy adhesives and honeycomb core material decompose at much lower temperatures. During the material testing program, while developing the honeycomb thermal model, ignition of the honeycomb core was noted to occur at approximately 250°F at atmospheric conditions. This phenomenum is, of course, not observed in a closed system without the necessary ignition mechanism. However, volatile gases are produced at this temperature which can migrate to the surface to support combustion in this area. Ignition is supplied by the heated liner hot gas surface and perhaps by the burning of fuel during the shutdown purge sequence.

Sufficient material is available within the liner itself to supply combustion. This is demonstrated by the recent ignition and destruction of a Stage II liner, S/N 163, during the post-oven cure operation. At atmospheric

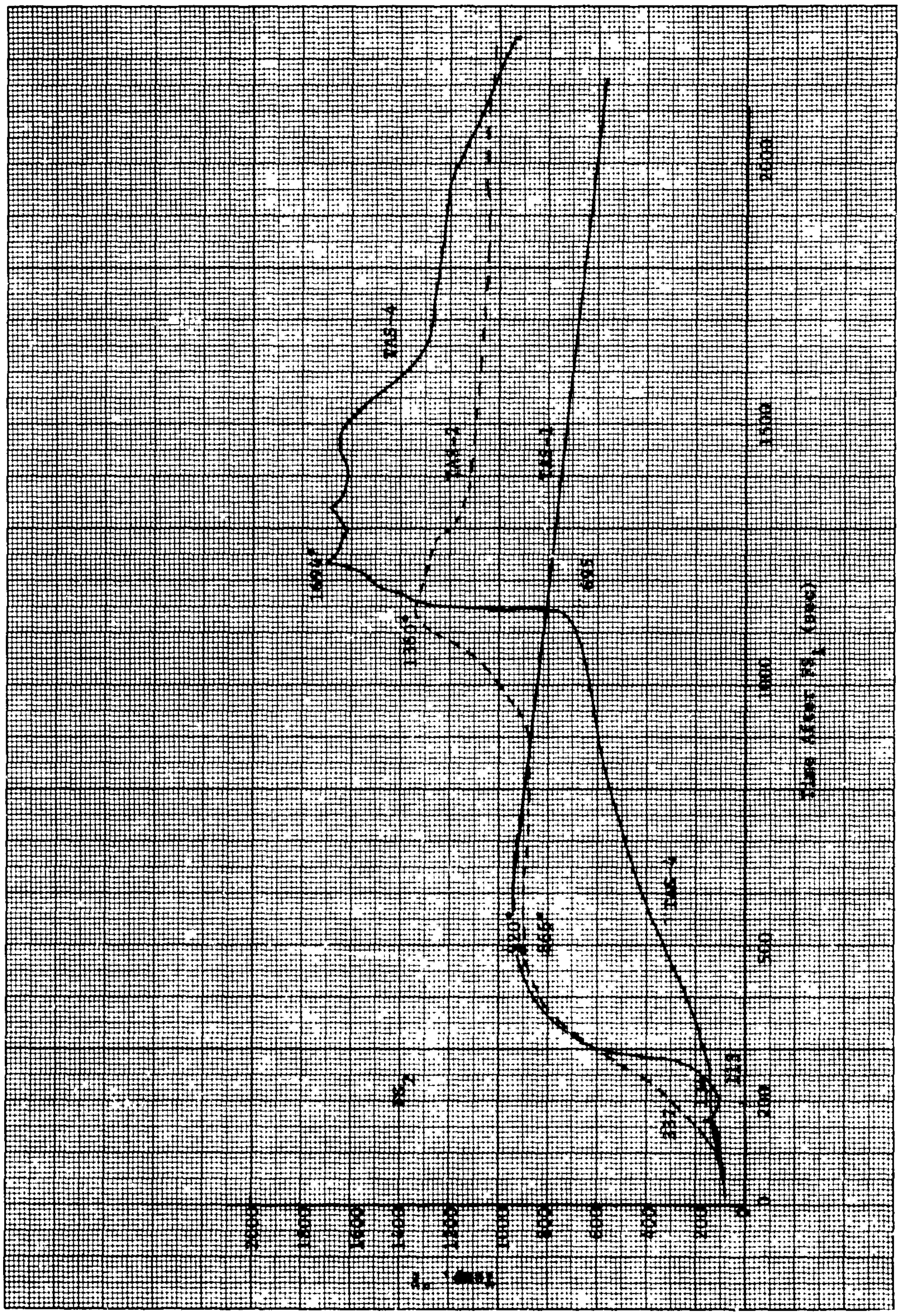

Figure 60 -- Liner and Outer Laminate Temperatures -- Ablative Skirt S/N 003

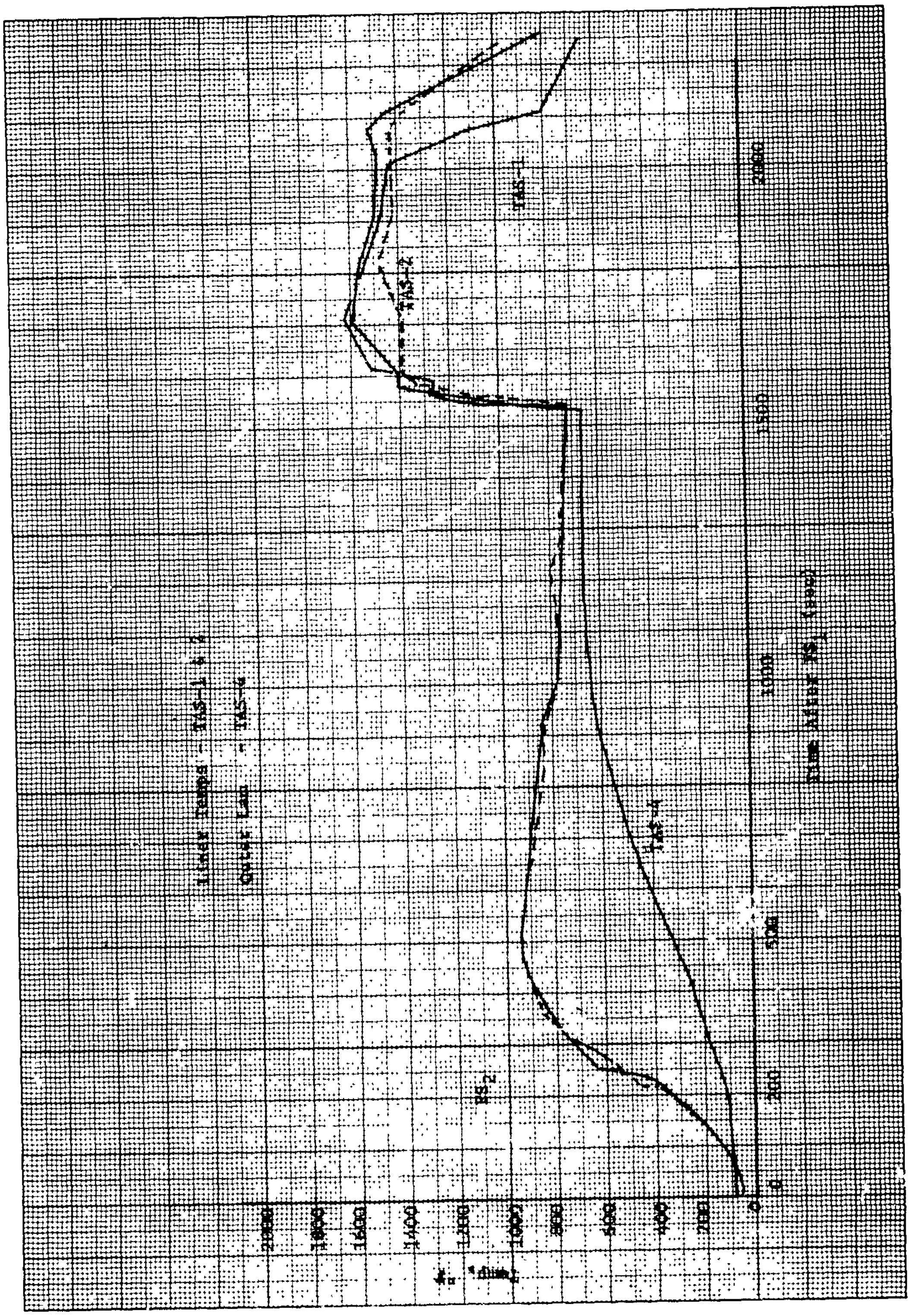

Figure 61 -- Liner and Outer Laminate Temperatures -- Ablative Skirt S/N 005

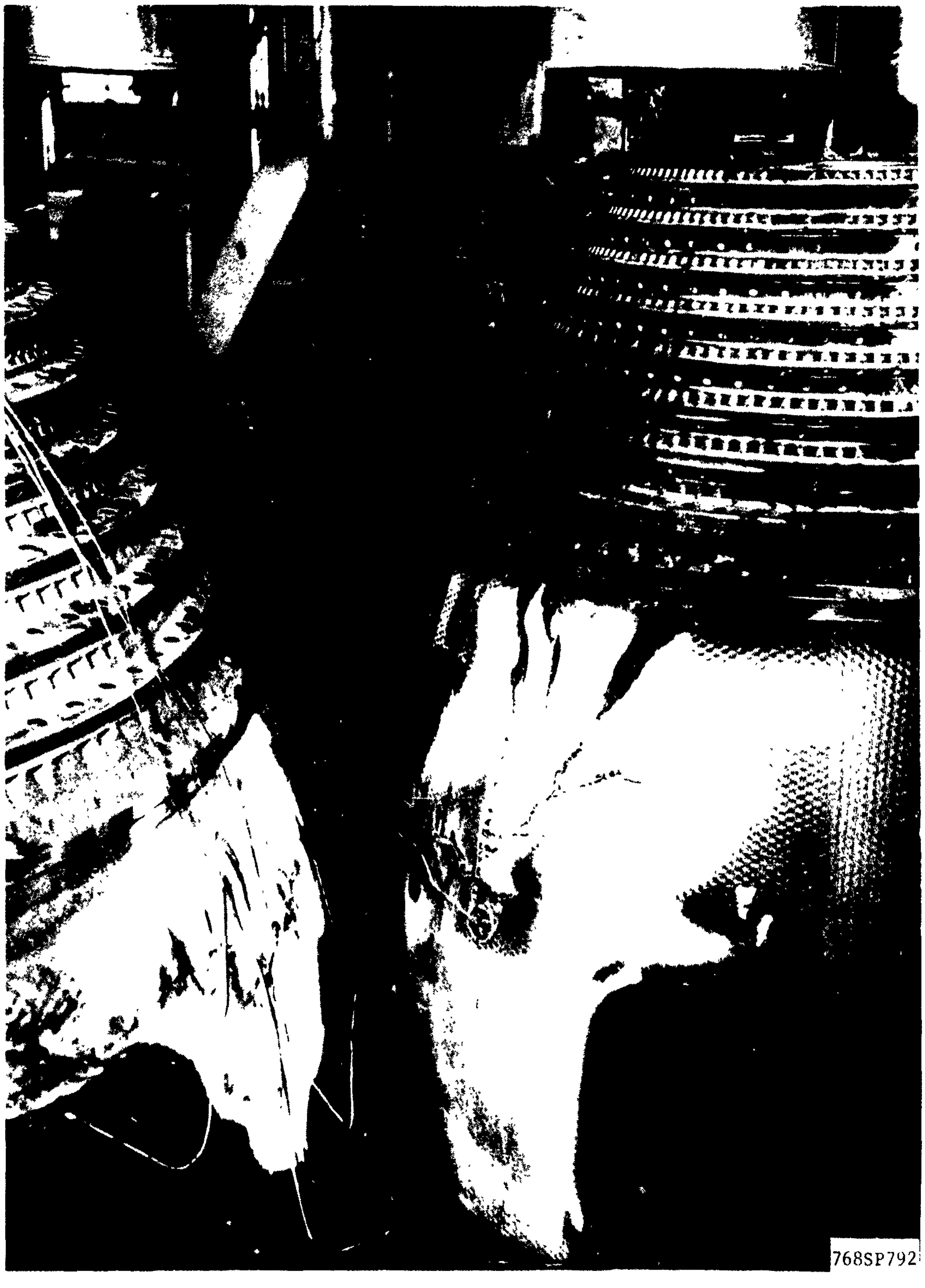

Figure 62 -- Burn Damage -- Skirts S/N 003 and S/N 005

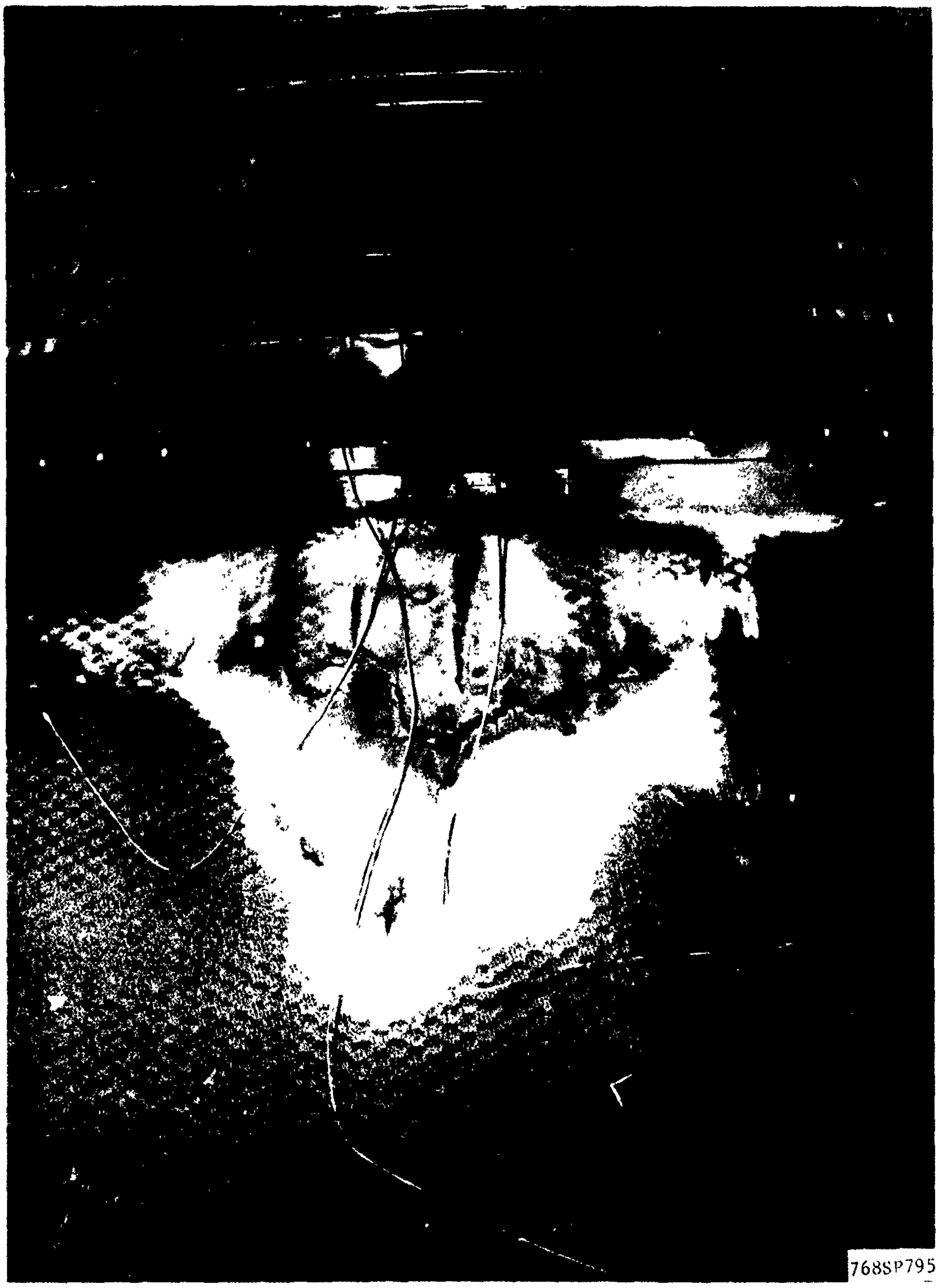

Figure 62 -- Burn Damage -- Skirt S/N 003

Figure 62 -- Burn Damage -- Skirt S/N 005

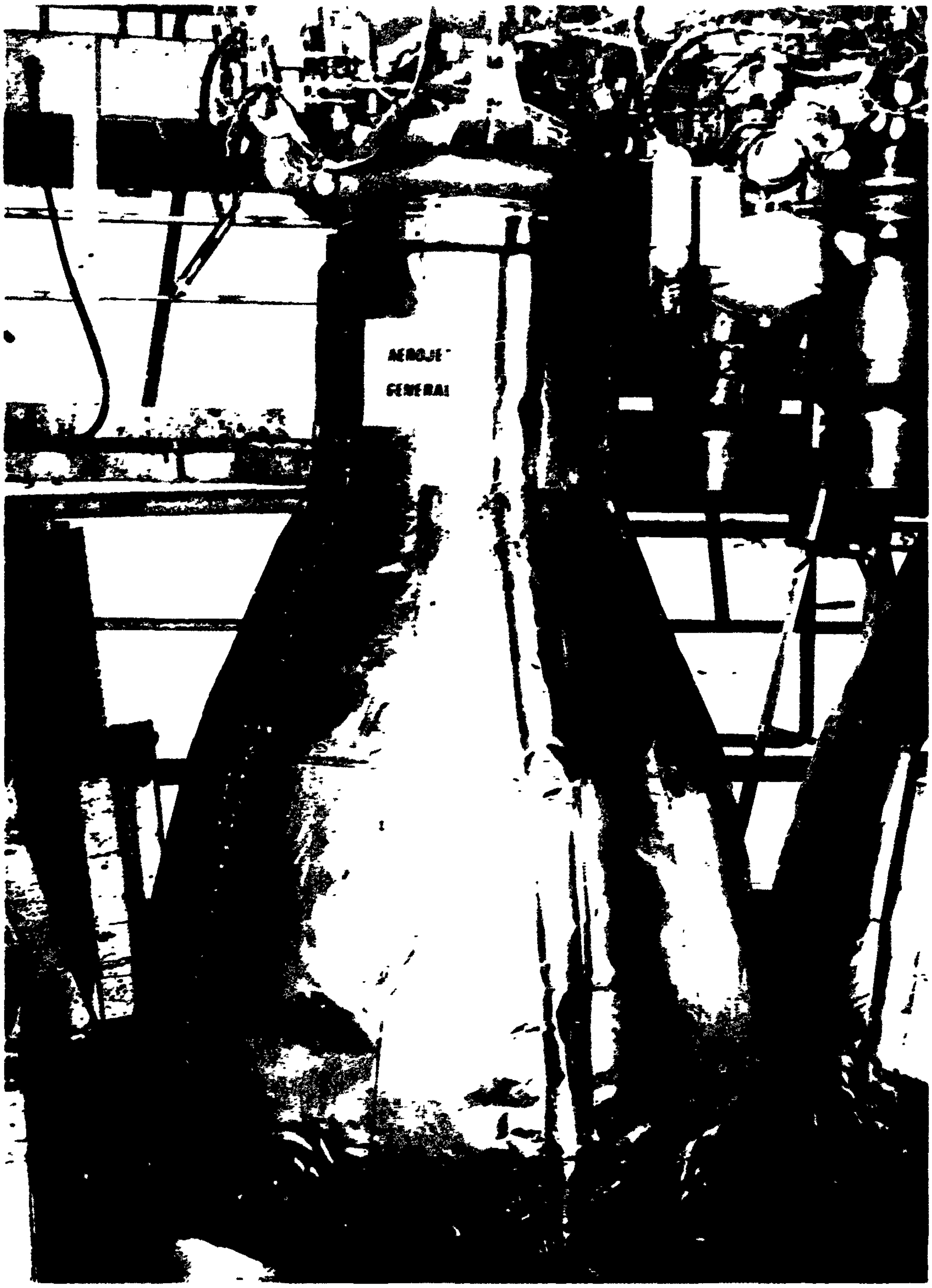

Figure 63 -- 12:1 Ablative Skirts with Modified Refrasil Covers

Table 37—Pyrolytic Products of Phenolic and Epoxy Systems (in Vacuo)

Volatized	Phenolic			Epoxy		
Component	932°F	1472°F	2192°F	932°F	1472°F	2192 F
Acetone	17.6			2.2		
Acetylene			1.9			
Benzene	2.5	0.7	9.0	1.3	2.8	8.1
Butane		6.8				
Carbon dioxide	0.6	0.6	1.2	6.0	3.7	1.8
Carbonmonoxide	3.5	9.4	2.2	3.1	11.2	25.9
Cyclopentadiene			0.9			0.6
Ethane					1.6	
Ethylene		1.8	1.6		3.0	3.0
Hydrogen		5.2	2.8		0.8	2.1
Methane	4.3	11.8	4.9	0.8	1.6	4.3
Pentane				0.5		0.7
Pentene						0.5
Propane				11.1		
Propanol	11.1					
Propylene		0.8	0.8	2.3	2.2	
Toluene	4.7	1.2	1.5			
Others			0.4	0.7		0.8
Unidentified high molecular wt compounds	49.9	59.9	72.8	82.0	73.1	50.9
Resin Volatilization	28%	47%	48%	75%	86%	87%
Resin Residue	72%	53%	52%	25%	14%	13%
Avg molecular wt of all Volatile components	76	24	41	146	71	36

4.3, Ablative Skirt (12:1) (cont.)

conditions, the products supporting the combustion are large molecular straight chain (unsaturated) and cyclic compounds. At altitude conditions (vacuum) the decomposition products available for combustion are shown to vary with the temperature bringing about the decomposition (see Table 37).

At altitude conditions, where the oxygen context is relatively low, burning of decomposition products from the structure is not a problem. Post-test fires will, however, continue to be a problem at static sea level test conditions and will probably necessitate a nitrogen purge under the insulation if additional tests of the skirt are required. It should be noted that the tighter fitting 15:1 panels have not exhibited this phenomena. This is probably because the tighter fit eliminates the supply of air necessary to support combustion.

4, Evaluation of Ancillary Components (cont.)

4.4 TITAN IIIB FLIGHT GIMBAL ACTUATORS (CCN 53)

A complete set of four Titan IIIB Sea-Level Launch Configuration Gimbal Actuators (P/N PD4600008-19) were installed on engine S/N 14 prior to test No. -214. The actuators, fabricated by Moog Inc., were instrumented, installed, and checked out under supervision of an engineer from the Martin-Marietta Corporation's Hydraulics Department. Incorporation of the Titan IIIB gimbal actuator into the Titan IIIM engine demonstration program was authorized by Contract Change Notice 53 to Contract Number F04695-67-C-0097.

The actuators were instrumented and installed on engine S/N 14 for the purpose of evaluating compatibility and performance during engine test exposure (see Figure 20).

No gimballing was planned or performed during the test; however, the actuators were pressurized by the facility hydraulic system. Data recorded and transmitted, for detailed evaluation by MMC, included measurements of actuator piston displacement and pressures and temperatures of the hydraulic fluid.

The actuators were not visibly affected by the test environment nor were there any difficulties associated with the installation of the actuators on the engine.

No assessment of the data has been received from MMC.

4, Evaluation of Ancillary Components (cont.)

4.5 FLIGHT INSTRUMENTATION PRESSURE TRANSMITTERS (Pld and PgGB)

4.5.1 Performance

Two pressure transmitters, one from each of two vendors, were tested to verify transmitter and installation compatibility with the engine operating environments. (See Table 38.) Testing was required as part of the qualification program for the new low-range pressure transmitters, P/N AS4479C50B, P/N AS4479C100B, and P/N 1156175-1. The test objective was to validate the flight configuration sensor for lube pump discharge pressure (Pld) and gearbox pressure (PgGB), including transmitters and pressure fittings. Because the transmitters in the flight configuration are mounted directly to the Pld and PgGB bosses, redundant measurements with test stand instrumentation (which would have required use of the T-fittings at the pressure ports) were not provided.

The 0-100 psia range pressure transmitter supplied by CEC (consolidated Electrodynamics Corporation) was directly mounted on the gearbox port of Subassembly 1 in the Pld position for all tests. The pressure transmitter, S/N T3570, was the identical unit previously subjected to vibration testing by CEC during qualification testing. During qualification the unit was subjected to random vibration per requirements of the Titan IIIM System Specification for Stage I engine mounted components; i.e., 48 g rms overall for 555 seconds in each axis. The same unit has also been subjected to the Stage II engine environment for 90 seconds, while installed in the 3-Pld position during Test No. 3051-B02-2A-001 of engine S/N RD-22. The transmitter, direct-mounted on the subassembly PgGB gearbox port, was also a unit that had previously been subjected to vibration testing during the transmitter qualification program. The 0-50 psia range unit, Taber Instruments, Inc., S/N 671437, was subjected to random vibration testing per the Titan IIIM System Specification for

Table 38 -- Flight Instrumentation Pressure Transducer Data

Component Description	Vendor	Vendor Part Number Test Item	Vendor Part Number Production	Item SN	Numbers	Total No. Tests	Total Test Dur. Sec.	Test Parameter	Remarks
1. Pressure Transmitters Spec: AGC-42427									
a. 0-50 psia AGC PN AS4479-C50B	Taber	MOD 187	A187-1028	671437	308, 310, 312, 315, 316	5	640	1-PgGB	Transmitter Qualification Not Completed
b. 0-100 psia AGC PN AS4479-C100B	CEC	362539-0101	362539-0100	T3570	308, 310, 312, 315 316	5	640	1-Pld	

Table 39 -- Test Data from Flight Instrumentation Pressure Transducers

Run No.	Duration	Pld-S/A-1 (psia) FS_1+10	FS_1+ 100	FS_2	CEC SN Installed	Pld-S/A-2 (psia) FS_1+10	FS_1+100	FS_2	PgGB S/A-1 (psia) FS_1+10	FS_1+100	FS_2	Taber SN Installed	PgGB S/A-2 (psia) FS_1+10	FS_1+100	FS_2
302	201.008	62	53.5	50	-	67	64	62	16	19.5	20.5	-	16.5	22	23
303	200.341	63.2	58.5	56	-	65	71	66.5	17	24	26	-	16	29	28.5
304	200.843	57	60	57	-	63	71	67	16	26	27	-	28	30	29
305	200.645	57	55	54	-	66	75	72	15	20	20	-	17	30.5	29.5
306	200.746	61	61	59	-	65	59	57	16	26	27.5	-	15	16	17
307	200.470	59	64.5	62	-	65	75	69	15.5	27	28	-	16.5	30.5	27.5
308	20.977	65	-	65	3570	71.5	-	71.5	15.5	-	18	671437	16	-	19
309	2.569	Malfunction													
310	200.361	62	65	59	3570	66	71	66.5	16.5	32	32	671437	17	30.5	28.5
311	21.340	57	-	56	-	56.5	-	56	15	-	15	-	15	-	15
312	201.114	60	53	49.5	3570	60.5	60	58	15.5	20.5	22	671437	16	23	24
313	20.845	59	-	59	-	60.5	-	61	15	-	15.5	-	14	-	15.5
314	200.908	59	56.5	54	-	60	63	62	15	17.5	18	-	16	23.5	25
315	21.095	65	-	64	3570	63	-	65	17	-	20	671437	16	-	19
316	200.809	61.5	66.5	60.5	3570	63	72	64.5	16	31.5	31	671437	17	31	30

Pld, PgGB Test Data - Demonstration Engine S/N 15
Test Series 3051-D07-1A-3XX T.S. G-2
Pld Transmitter: CEC P/N 362539-0101 PgGB Transmitter: Taber Series 187

4.5, Flight Instrumentation Pressure Transmitters (Pld and PgGB) (cont.)

Stage II engine mounted components; i.e., 68 g rms overall for 675 seconds per axis.

Test data for Pld and PgGB measurements during Tests No. -302 through No. -316 are shown in Table 39. Measured values are shown for each subassembly at the FS1 plus 10 seconds and FS2 points for the 20-second tests.

4.5.2 Vibration Environment

The vibration environment for pressure transmitters mounted directly to gearbox pressure ports Pld and PgGB was determined in order to support the qualification of transmitter designs selected for in-flight measurement of these parameters. Vibration data for this particular area of the gearbox is unavailable and the use of lightweight, direct-mounted units for gearbox measurements has not been previously attempted.

Three single-axis accelerometers were installed on engine Subassembly 1 at points between and equidistant from the Pld and PgGB pressure ports, and data were recorded from five engine tests. PSD plots were calculated for two of these tests and the results are shown in the composite plot. Figure 64 shows the maximum energy levels for each axis obtained for the two runs. A PSD maximum envelope is plotted and the corresponding overall g rms approximated for comparison purposes. The 33.5 g rms overall level shown in Figure 64 is notably less than the Stage I engine mounted equipment level (48.8 g rms) of SS-TIIIM, Figures 3 -20, in accordance with which the CEC transmitter was tested during component qualification testing.

Three single-axis accelerometers were mounted on both the Pld and PgGB pressure transmitters (external surface) to evaluate the stress that could be reflected to the pressure port fittings during engine firing. Installation details were as follows:

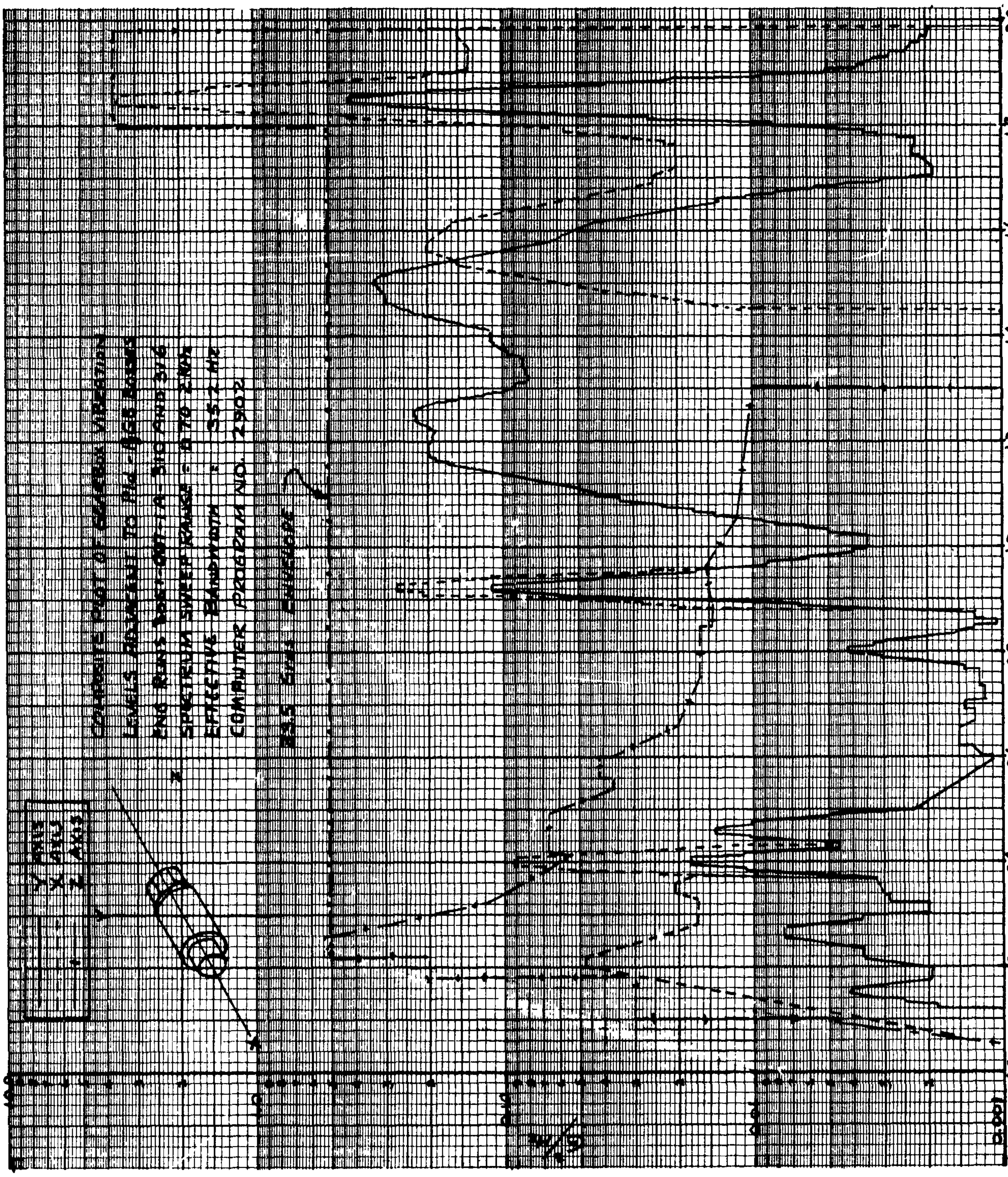

Figure 64 -- Gearbox Vibration Levels -- P_{1d} and P_{gGB} Locations

4.5, Flight Instrumentation Pressure Transmitters (Pld and PgGB) (cont.)

Location	Transmitter P/N	Transmitter Weight Incl. Connector	Accel. Location from Press. Port	g rms/Axis Y	Z	X
PgGB	Taber - Mod. 187	11.0 oz	1.5 in.	20	32	28
Pld	CEC 362539-0101	4.5 oz	1.25 in.	19	17	11

The Pld pressure port fitting is a MS24399C3 reducer, 1/4 in. to 3/16 in. The 3/16 in. end mates with the gearbox port. The PgGB union is a standard 1/4 in. fitting. The PSD plot of Figure 64 was computed from the PgGB accelerometer data and the g rms as determined (approximately) for each axis was used to compute the resultant stress transmitted to the union. Figure 65 represents similar PSD plots computed from the Pld accelerometer data (not shown) but with energy levels lower than indicated above.

The results of this analysis indicates large factors of safety for both transmitter and gearbox fittings, e.g., with the higher g rms levels of the PgGB transmitter applied to the 3/16 in. Union (MS24399C3) the safety factor was determined to be greater than 2.

Based on the foregoing test results, it is concluded that the CEC 362539-0101 transmitter (AGC P/N AS4479-C100B and -C50B), which was the primary design selected for gearbox pressure measurements, is compatible with the engine environment and suitable for flight use.

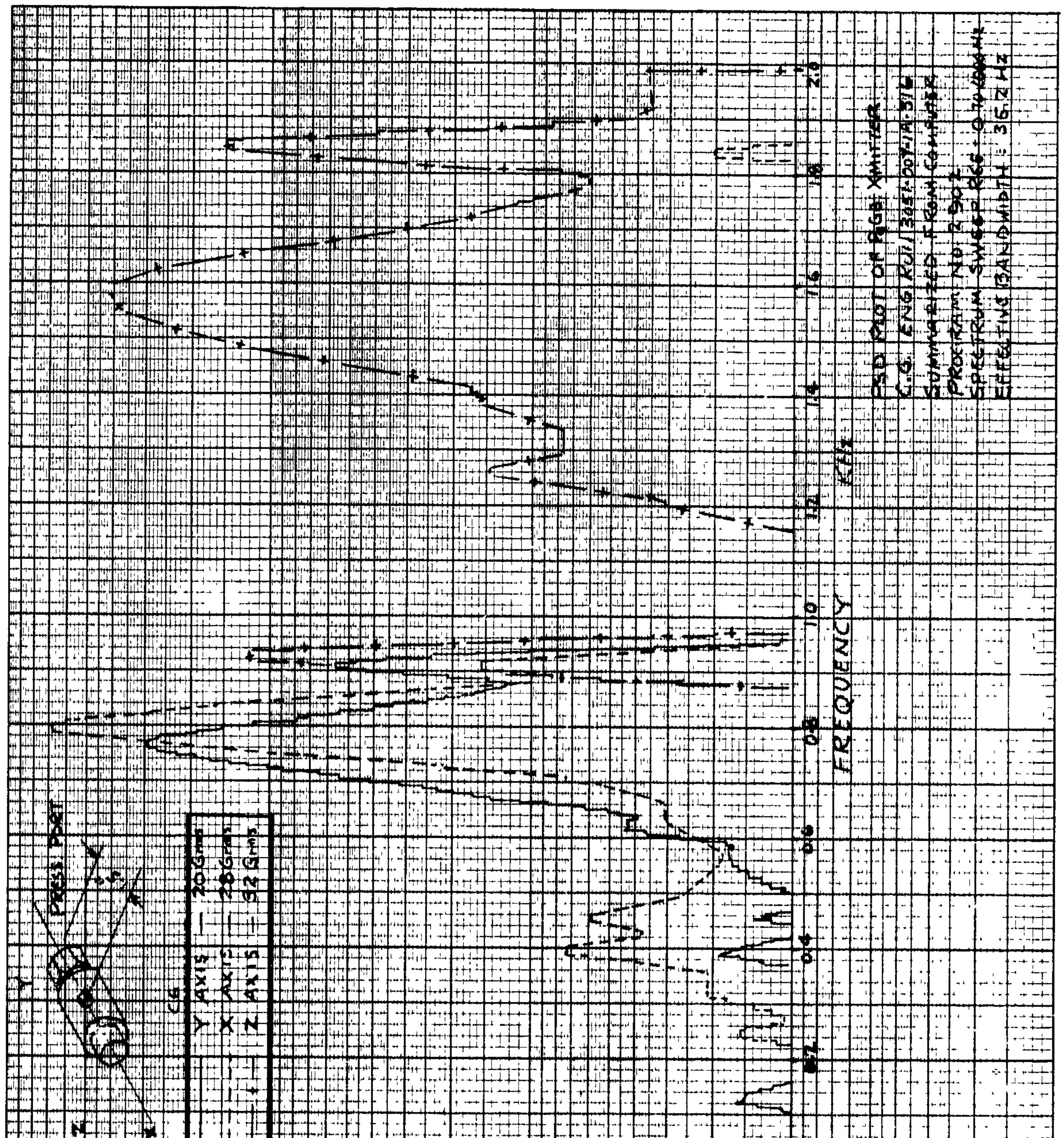

Figure 65 -- Spectral Density Plot -- P_{1d} Accelerometer Data

5. Miscellaneous Special Evaluations

5.1 Fuel Check Valve with Low Pressure Drop

5.2 Lube Pump Lock Ring

5.3 Leak Check Procedure for Fuel Manifold Cavity

5. MISCELLANEOUS SPECIAL EVALUATIONS

5.1 FUEL CHECK VALVE WITH LOW PRESSURE DROP

In the past, the back pressure on the fuel venturi was calculated using PfJGG and an estimated pressure drop across the fuel check valve and bootstrap line. The pressure drop of the check valve is fairly large and can have a significant effect on the calculated venturi pressure ratio. As mentioned in Section 2, during some of the demonstration tests a special pressure tap adapter was installed between the gas generator line and the fuel check valve to measure the pressure at the check valve (PfCKV) directly. The resistance of all four check valves on both demonstration engines was thus obtained, plus the resistance of an experimental check valve with low pressure drop. Data for the latter valve were obtained from only one test.

Prior to testing, a typical resistance of 0.55 had been used for fuel check valve calculations and was based on hydrotest data of a single prototype valve. The check valve data derived from the demonstration testing are tabulated in Table 40, with the resistances ranging from 0.550 to 0.466 for the standard valves, P/N 705574. The resistance derived on the single test of the experimental valve was 0.533, not as low as expected, possibly due to its location at a right angle to the PFCKV pressure top adapter just upstream of the valve.

Table 40 — Fuel Check Valve Resistances

Special Instrumentation: PFCKV at inlet to check valve, only on tests listed below.

Sub-Assembly	Test Series No.	Time Period, sec	WFGG, lb/sec	SGFGG	ΔPFCKV, psi	Resistance RFJGG	Check Valve P/N	Check Valve S/N
Demo Engine S/N 14								
1	-209	19-21	11.96	0.921	84	0.542	705574	504
1	-210	101-121	11.96	0.920	86	0.559		
					Average	0.550		
2	-211	9-11	13.96	0.908	107	0.501	705574	506
2	-212	101-121	13.84	0.894	104	0.488		
2	-213	2-20	12.06	0.905	81	0.506		
2	-214	2-201	12.26	0.892	86	0.510		
					Average	0.501		
Demo Engine S/N 15								
1	-306	2-200	12.47	0.908	74	0.518	705574	505
1	-307	2-200	12.39	0.908	81	0.481		
1	-308	2-20	12.78	0.910	85	0.476		
1	-310	2-200	12.63	0.894	88	0.495		
1	-311	2-20	11.13	0.909	74	0.474		
1	-312	2-200	10.91	0.893	63	0.474		
1	-313	2-20	11.36	0.920	64	0.456		
1	-314	2-200	11.23	0.920	63	0.464		
1	-315	2-21	12.28	0.908	76	0.457		
1	-316	2-200	12.94	0.921	84	0.466		
					Average	0.476		
2	-306	2-20	13.82	0.907	87	0.484	705574	507
2	-307	2-200	13.72	0.906	96	0.465		
2	-308	2-20	13.94	0.908	97	0.455		
2	-310	2-200	13.77	0.895	96	0.454		
2	-311	2-20	11.91	0.908	71	0.460		
2	-312	2-200	11.72	0.893	71	0.465		
2	-313	2-20	12.62	0.919	84	0.488		
2	-314	2-200	12.44	0.919	76	0.453		
					Average	0.466		
Demo Engine S/N 14								
1	-215	2-200	13.43	0.921	104	0.533	X8230 -16MA (Low pressure design)	X-1

5, Miscellaneous Special Evaluations (cont.)

5.2 LUBE PUMP SNAP RING

Two lube pump snap-ring failures were discovered during the Titan IIIM turbopump development program. The mode of failure was dislocation of the snap rings from the housing groove. The purpose of the snap rings is to retain the two end bearings in the housing. A stack of four Belleville washers between the supply and scavenge pumps imposes a load on the end bearings which in turn must be carried by the snap rings. The end bearings were found to have comparatively large chamfers in the area mating with the snap ring. The chamfers exposed the snap rings to a bending force rather than to the desired shear force. This bending force resulted in the lock rings being angularly deflected or bowed relative to the pump housing.

The lube pumps on engine S/N 15 were replaced with pumps that had been reworked by eliminating the chamfer from the end bearings, producing sharp corners which significantly reduced the degree of snap ring distortion. In order to determine whether the snap ring distortion was caused by the operational environment, the lube pumps were removed after Test No. -305. Inspection after 823.5 sec of operation revealed that the posttest snap ring distortion had not measurably increased relative to the pretest measurements.

5, Miscellaneous Special Evaluations (cont.)

5.3 LEAK CHECK PROCEDURE FOR TURBINE MANIFOLD CAVITY

An evaluation was made during the engine testing to determine the effect on the temperature of the turbine shaft lower bearing of residual fluids left in the cavity formed by the turbine manifold after checks for static seal leakage. The configuration of the cavity results in a quantity of the fluid being trapped at this point, which is adjacent to the turbine shaft lower bearing.

Unusual bearing temperature rise rate characteristics were observed during the Titan IIIM turbopump development program. It was suspected that the bearing temperature was influenced by the absorption of turbine heat by the residual leak check fluid (latent heat of vaporization). In order to evaluate this possibility different leak check fluids were used during two of the engine demonstration tests. Before Test No. -312 water was used with Subassembly 1 and Freon with Subassembly 2 to conduct the leak test. Before Test No. -314, Freon was used with Subassembly 1 and water with Subassembly 2. Freon was chosen for the alternative fluid because it is highly volatile and vaporized completely prior to firing.

Evaluation of the bearing temperature rise rate data is inconclusive. The bearing temperature rise rate data indicated that the bearing temperature is primarily a characteristic of each TPA. The Subassembly 1 (TPA 009) bearing temperatures were higher than Subassembly 2 (TPA 011) on both of these tests. The Subassembly 1 temperature was higher using water than with Freon, and the Subassembly 2 temperature was higher with Freon than with water.

The TPA data from the engine tests were compared to the TPA acceptance test data. This comparison indicates that bearing temperature rise rate characteristics may be related to the type of test; e.g., turbopump or engine.

5.3, Leak Check Procedure for Turbine Manifold Cavity (cont.)

The results of these tests do not indicate that there is a correlation between the amount of residual leak check fluid and the bearing temperature rise rate characteristics. The quantity of residual leak check fluid remaining in the turbine manifold cavity prior to test is unknown. Sufficient time may have elapsed between the leak check and the test firing for even the water to have evaporated.

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6. Discussion of Dis:repancies

6.1 Engine Components

6.2 Thrust Chamber Assembly

6.3 Turbopump Assembly

6.4 Engine Controls

6.5 Gas Generator Assembly

6. DISCUSSION OF DISCREPANCIES

This section presents the engineering evaluation of the significant discrepancies observed and documented during the Engine Demonstration test program and subsequent disassembly.

All discrepancies noted during the test program are listed in Appendix D with a brief discription of the incident and the disposition made. The summary is arranged by the major component assemblies with separate sections for engines S/N 14 and S/N 15. Included are the accumulated time and cycle data at the time of the discrepant condition and the Inspection Report numbers as available.

6.1 ENGINE COMPONENTS

6.1.1 Oxidizer Suction Line Pn 294251

Excessive bellows distortion was observed on oxidizer suction line S/N 625 after Test No. -214 (see Figure 66). The line had been subjected to 1624 seconds of engine testing while installed on engine S/N 14, Subassembly 1. Oxidizer suction line S/N 628, which replaced S/N 625, was also found to have excessive distortion (See Figure 67). One 200 second test had been conducted with this line installed. The degree of distortion appeared to be similar in both cases. Subsequent to completion of demonstration testing the oxidizer suction lines on both subassemblies of engine S/N 15 and the line installed on Subassembly 2 of engine S/N 14 were found to have normal amount of distortion.

Oxidizer suction pressure spikes and engine interface alignment were reviewed to determine the cause of the discrepancies. The review disclosed that the maximum suction pressure spikes during tests No. -214 and No. -215 were lower in magnitude (395 psia and 410 psia respectively)

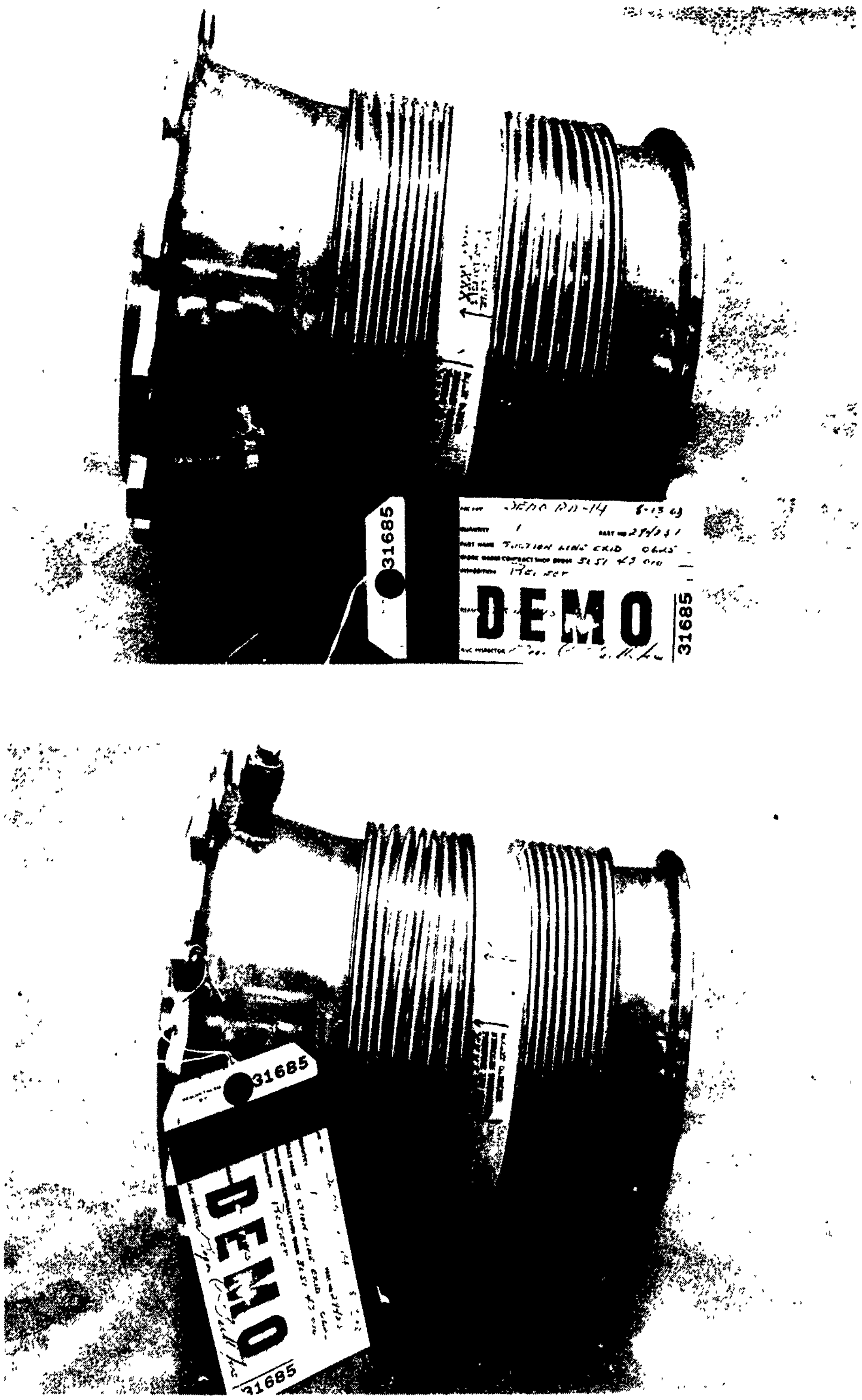


Figure 66 -- Oxidizer Suction Line S/N 625

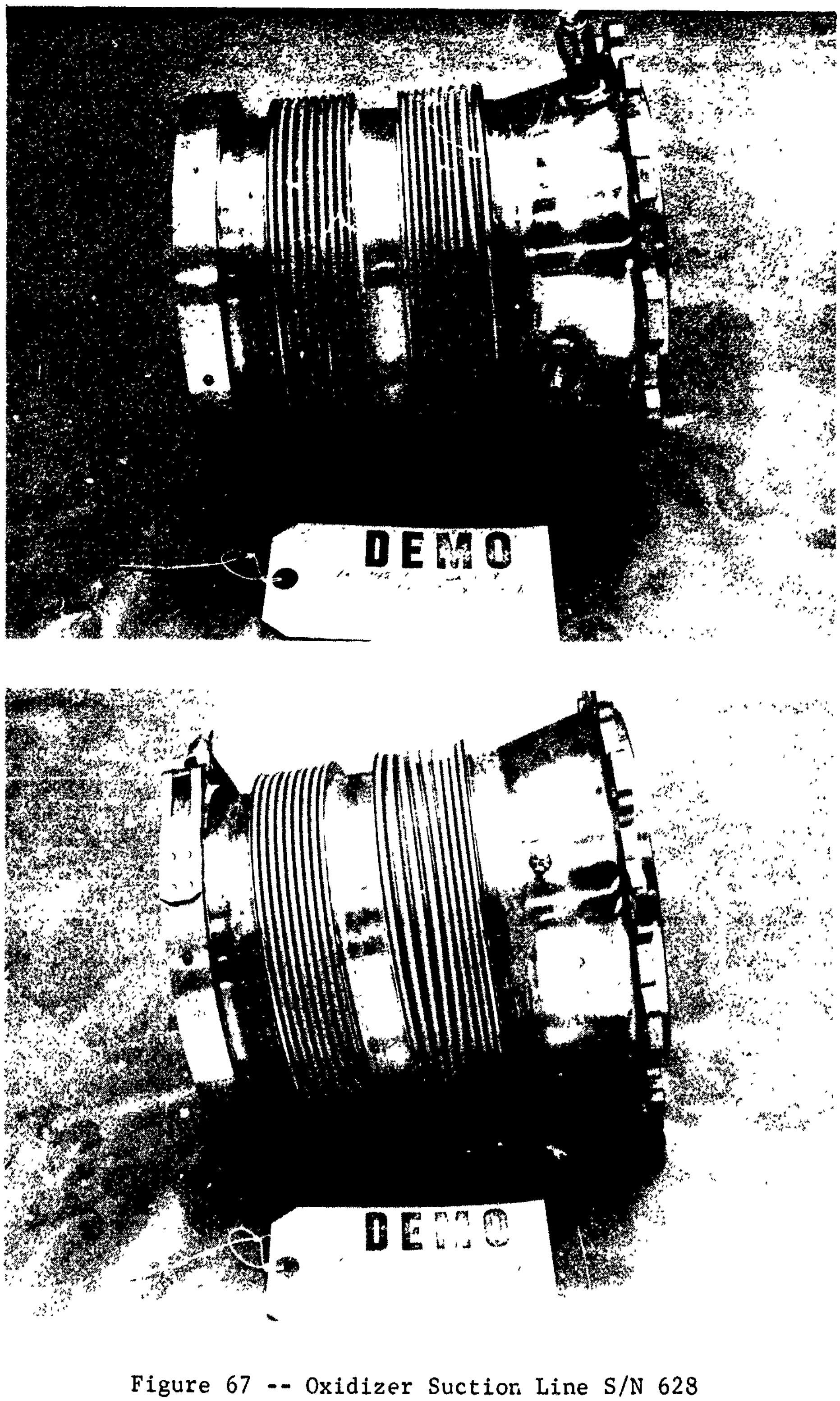


Figure 67 -- Oxidizer Suction Line S/N 628

6.1, Engine Components (cont.)

than experienced during a significant number of engine demonstration tests. Suction pressure data retrieved using Taber pressure transducers was available for this comparison.

Test stand oxidizer line alignment checks revealed some misalignment on Test Stands G-1 and G-2 with the greater amount of misalignment on Test Stand G-1. Each line was realigned and firmly secured. No additional incidences of oxidizer suction line distortion occurred subsequently.

It is concluded that the distorted suction lines noted on engine S/N 14 were the result of engine-to-test stand misalignment.

6.1.2 Fuel Bootstrap Hose S/N 542, P/N 259387

During the routine postfire leak checks after Test No. -304, leakage was observed near both ends of the fuel hose S/N 542. The leak check was conducted at 50 psig lockup using gaseous nitrogen (GN_2). A pressure decay rate was not recorded at this time. The similar line on Subassembly 1 did not leak.

The hose was again leak checked in the Aerojet hydrolab facility and leakages were verified. Using a lockup pressure of 100 psig GN_2, the pressure decay measured 80 psi in 30 sec. The leakage was noted at 7 in. and 9 in. from each end, respectively.

The hose was returned to the vendor for examination and analysis. Removal of the wire braid exposed a jagged split in the black teflon liner at each leakage location.

6.1, Engine Components (cont.)

The results of the vendor's failure analysis suggest the splits in the hose liner were caused by bumping or jarring of the hose after extrusion but before sintering. As a result of mishandling, the sintering process may not always provide a good bond between the teflon crystals and weak spots in the liner may develop. The vendor further states that a few incidents of similar failures, at about the time hose S/N 542 was fabricated, led to corrective measures regarding the handling processes and additional integrity procedures. These measures included a 500-cycle, 0 to 2500 psi, 70 cpm impulse test at -65°F as weak spots are made prominent by working at low temperature.

Leakage, if existent during the test, was not apparent in either motion picture or data reviews; therefore, the anomaly was considered minor. There are no indications that leakage was caused or incurred during the shutdown transient or postfire procedures.

The hose had experienced four engine tests with a total duration of 622.8 sec accrued at the time of failure. This is the first failure of this nature on this hose during an engine test.

6.1.3 Propellant Discharge Lines

Engine S/N 14 was tested using oxidizer discharge line P/N 265382-19 and fuel discharge lines, P/N 256866-19. These lines are of the early Titan design configurations which did not incorporate the interference-fit inserts in the tripod assemblies. Consequently the lines were cited frequently for abnormal bellows/tripod dimensions.

6.1, Engine Components (cont.)

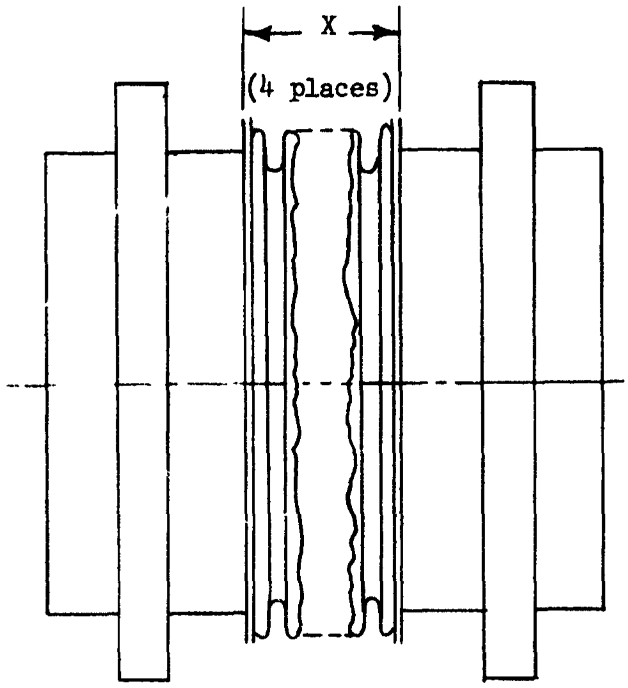
The dimensional criteria associated with these lines (see Figure 68), were established during the basic Titan program to ensure that the structural integrity of the lines was not endangered should a tripod insert become dislocated. Subsequent experience and experimentation has shown this criterion to be very conservative. Therefore, as the anomalous conditions occurred on the Engine S/N 14 lines, the bellows dimensions were documented and the condition accepted "as-is" for retest.

During the first three tests with Engine S/N 14 the oxidizer line bellows measurements exceeded the minimum value of 2.10 in. as much as 0.10 in. and the fuel line bellows exceeded the minimum of 1.95 in. by as much as 0.086 in. Pressurization of the lines (propellant systems) to 50 psig, coupled with manual TCA gimballing, would substantially improve the dimensional discrepancies and frequently restore the bellows lengths above the minimum values. At no time during the tests were any of the inserts completely dislocated or damaged.

6.1.4 System Leakage

After each test of the demonstration engine, static leakage tests of propellant, hot-gas, autogenous pressurization, and electrical harness systems were conducted. Static system leak checks were also conducted subsequent to initial engine installation on the test stand and prior to each test.

The allowable leakage rates are presented in Table 41. The results of the systems leak checks are presented in Table 42.



Oxidizer -- Minimum Average Length = 2.10 inches

Fuel -- Minimum Average Length = 1.95 inches

Figure 68--Propellant Discharge Lines Bellows Dimensions

Table 41 — Allowable Leakage Rates

Item	Test Pressures	Allowable Leakage
Fuel System	50 ± 5 psig	2 psig in 5 minutes exclusive of pump seal leakage No external leakage allowable by liquid leak detection method
Oxidizer System	50 ± 5 psig	2 psig in 5 minutes exclusive of pump seal leakage No external leakage allowable by liquid leak detection method
P 5	350 ± 15 psig	Zero decay in 5 minutes
Hot Gas System	50 ± 5 psig	No external leakage allowable by liquid leak detection method Zero decay in 5 minutes
Autogenous Systems	50 ± 5 psig	(1) Zero decay in 5 minutes (2) No internal gas cooler leakage allowable for 10 minutes by bubble leak check method
Electric Controls	10 ± 1 psig	Zero decay after 2 minutes
Propellant Supply System (TCA and GGA)	50 ± 5 psig	No leakage allowable by liquid detection method
Oxidizer Pump Seal	50 ± 5 psig	900 cc/min (least leakage)
Fuel Pump Seal	50 ± 5 psig	900 cc/min (least leakage)
Oxidizer Gearbox Seal	15 ± 1 psig	300 cc/min (least leakage)
Fuel Gearbox Seal	15 ± 1 psig	300 cc/min (least leakage)
Turbine Seal	50 ± 5 psig	[illegible] cc/min (least leakage)

X = Fuzz leakage by liquid soap leak detection method.

Zero leakage unless otherwise indicated.

Table 42 -- Prefire/Postfi

YLR 87-AJ-11, Engi

Prefire Leak C

	Test No.	201		202		203		204		205		206		207	
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
	Fuel Gear Seal														
	Oxid Gearbox Seal														
Upstream TCVs	Lube Oil Cooler, cc/min														
	Superheater Coils, cc/min														
	Other														
	Final Decay Rate, Fuel psi/5 min														
	Final Decay Rate, Oxid psi/5 min	1/2	1/4							1/2					
	Fuel Pump Seal, cc/min														
	Oxid Pump Seal, cc/min	75	50		25					100		100		80	1
	Turbine Seal, cc/min				260	150	220								14
Hot Gas System	Superheater/2nd Nozzle				Deleted										
	2nd Nozzle/Turbine Manifold					X		X		X	X	X	X	X	X
	Turbine Manifold/Cooler Inlet Line			X										X	X
	Inlet Line/Hot Gas Cooler				X		X						X		X
	Hot Gas Cooler/Outlet Line														
	FPBO Flange				X		X				X		X		X
	Turbine Manifold/Gearbox														
	GGA/Turbine Manifold	X	X	X	X	X	X	X				X	X	X	X
	Other							2		2	2	4	6		
	Final Hot Gas Decay, psi/5 min				1	2									
TCA Systems	Bootstrap System, Fuel/Oxid														
	Elbow Weldments, Fuel/Oxid														
	Dome/Injector														
	Injector/Combustion Chamber														
	Fuel Leakage thru Epon, cc/min														
	Hot Gas Leakage thru Epon, cc/min														
	Other		X PC6F Pick Up												
	TCA - Final Decay, psi/5 min														

1

le 42 -- Prefire/Postfire Leak Check Data

YLR 87-AJ-11, Engine S/N 14

Prefire Leak Checks

Test Series: 3051-D07-1A

5	206		207		208		209		210		211		212		213		214		215	
SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
							5										180			
													Oxid Pump Seal X	X Oxid Pump Seal						
													1/2	1/4				1		
	100		80	10			10		5		20						1400	15		
				140		420			150	150			1100	480		240		750		
											X	X	X	X						
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
			X	X	X			X		X				X			X	X		
		X		X						X				X				X		
X		X		X		X		X						X				X		
	X	X	X	X	X	X				X			X	X			X	X		
2	4	6							1	2	1/2		1	3/4	1/2	1/4	1	1-1/2		
										X										

2

X - Fuzz leakage by liquid soap leak detection method.

Zero leakage unless otherwise indicated.

Table 42 -- Prefire/Postf

YLR 87-AJ-11,

Prefire L

	Test No.	201		202		203		204		205		206		20
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1
Propellant System Upstream TCVs	Gearbox and Lube System													
	TCOV Lip Seal, cc/min													
	TCFV Lip Seal, cc/min													
	Lube Oil Cooler, cc/min													
	Super Heater Coils, cc/min													
	Other													
	Final Leakage Rate, psi/5 min													
Hot Gas System	Turbine Seal, cc/min					200	320	50						100
	Superheater to 2nd Nozzle													
	T.M. to 2nd Nozzle											X	X	
	H.G. Inlet at T.M.													
	H.G. Inlet at Cooler													
	H.G. Outlet at Cooler													
	FPBO Flange								X					
	Burst Disphragm Flange													
	T.M. to Gearbox													
	Gas Generator to T.M.													
	Other													
	Prefire Hot Gas Decay, psi/5 min							1/2						
TCA Propellant Systems Downstream TCVs	OBTL at OBTV													
	OBTL at Strainer or Elbow													
	FBTL at FBTV													
	FBTL at GGFCKV													
	FBTV at Elbow													
	Vane Welds, Fuel Elbows													
	Vane Welds, Oxid Elbows													
	Oxid Dome to Injector													
	Injector to Combustion Chamber													
	Combustion Chamber Wire Wrap													
	Other													
	Oxid Autogenous, psi/5 min													
	Elect Harness Conduit, psi/2 min													

-- Prefire/Postfire Leak Check Data (cont.)

YLR 87-AJ-11, Engine S/N 14

Prefire Leak Checks

Test Series: 3051-D07-1A

	206		207		208		209		210		211		212		213		214		215	
2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
																			X Oxid Pump Sea	
														Oxid	1/2	1/2	Oxid		2	Oxid
			100		150										1100	450	60		340	
												X	X	X						
	X	X			X	X							X		X	X	X		X	X
																				X
					X	X														
					1/2										1	3/4			1/4	
										X										
												X Fuel Inlet Elbox to Torus								
																	10			

2

X = Fuzz leakage by liquid soap leak detection method.

Zero leakage unless otherwise indicated.

* Greater than 18,000 cc/min

Table 42 -- Prefire/Postfire

YLR 87-AJ-11, En

Prefire Leak

	Test No.	301		302		303		304		305		306		307	
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-
	Fuel Gearbox Seal														
	Oxid Gearbox Seal														
Upstream TCVs	Lube Oil Cooler, cc/min														
	Superheater Coils, cc/min														
	Other														
	Final Decay Rate - Fuel, psi/5 min														
	Final Decay Rate Oxid, psi/5 min														
	Fuel Pump Seal, cc/min	20		20		5				10	10			25	
	Oxid Pump Seal, cc/min			80							10		50	*	*
	Turbine Seal, cc/min						80				1300		150		
Hot Gas System	Superheater/2nd Nozzle														
	2nd Nozzle/Turbine Manifold			X	X				X	X	X			X	X
	Turbine Manifold/Cooler Inlet Line								X	X		X	X	X	
	Inlet Line/Hot Gas Cooler								X				X		
	Hot Gas Cooler/Outlet Line														
	FPBO Flange				X		X		X		X				X
	Turbine Manifold/Gearbox														
	GGA/Turbine Manifold			X	X		X	X	X	X	X			X	X
	Other														
	Final Hot Gas Decay, psi/5 min						2			6	7	1/4	1/4		
TCA Systems	Bootstrap System, Fuel/Oxid														
	Elbow Weldments, Fuel/Oxid														
	Dome/Injector														
	Injector/Combustion Chamber														
	Fuel Leakage thru Epon, cc/min														
	Hot Gas Leakage thru Epon, cc/min														
	Other								X Fuel Bootstrap Line						
	TCA - Final Decay - psi/5 min								6						

1

ble 42 -- Prefire/Postfire Leak Check Data (cont.)

YLR 87-AJ-11, Engine S/N 14

Prefire Leak Checks

Test Series: 3051-D07-1A

	305		306		307		308		309		310		311		312		313		314		315	
	-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
												100										
	10	10			25						10											
		10		50	*	*	*	*			*	*								10		
		1300		150								600			190					2000		
	X	X			X	X	X	X			X	X	X		X	X			X	X	X	X
	X		X	X	X																X	
				X				X								X				X		
		X				X		X						X		X				X		
	X	X			X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
	6	7	1/4	1/4			1/2					4.5	1/4	1/8			SA-2 GGOCKV Reverse 12,000 cc/min					11
el Bootstrap Line																	1/2	1	Tube #123 Ext. leakage at weld wire lock band flange			X

2

X = Fuzz leakage by liquid soap leak detection method.

Zero leakage unless otherwise indicated.

* Greater than 18,000 cc/min

Table 42 -- Prefire/Postfire

YLR 87-AJ-11, En

Prefire Leak

	Test No.	301		302		303		304		305		306		307	
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-
	Gearbox and Lube System														
Propellant System Upstream TCVs	TCOV Lip Seal, cc/min					1									
	TCFV Lip Seal, cc/min														
	Lube Oil Cooler, cc/min														
	Superheater Coils, cc/min														
	Other					X Oxid Pump Seal									
	Final Leakage Rate, psi/5 min					1 Oxid								1 Oxid	O
Hot Gas System	Turbine Seal, cc/min														3
	Superheater to 2nd Nozzle														
	T.M. to 2nd Nozzle													X	X
	H.G. Inlet at T.M.							X				X			
	H.G. Inlet at Cooler														
	H.G. Outlet at Cooler														
	FPBO Flange														
	Burst Diaphragm Flange														
	T.M. to Gearbox														
	Gas Generator to T.M.							X							
	Other														
	Prefire Hot Gas Decay, psi/5 min													1/4	1/
TCA Propellant Systems Downstream TCVs	OBTL at OBTV														
	OBTL at Strainer or Elbow														
	FBTL at FBTV														
	FBTL at GGFCKV														
	FBTV at Elbow														
	Vane Welds, Fuel Elbows														
	Vane Welds, Oxid Elbows														
	Oxid Dome to Injector														
	In ·ctor to Combustion Chamber														
	Combustion Chamber Wire Wrap														
	Other									X Elbow at TC, seals repl					
	Oxid Autogenous														
	Elect Harness Conduit														

1

YLR 87-AJ-11, Engine S/N 14

Prefire Leak Checks

Test Series: 3051-D07-1A

	306		307		308		309		310		311		312		313		314		315	
A-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
		1	Oxid	Oxid	*	* Oxid									X {Oxid Autogenous Supply to Burst Disc Assembly}					
				300		400									100					
			X	X	X	X											X			
	X																			
														X						
								X												
					X	X	X	X							X	X	X	X		
			1/4	1/4		1									1/4					
bow at TC, seals replaced									Deleted per SA TRS 67	Deleted per SA TRS 67										

2

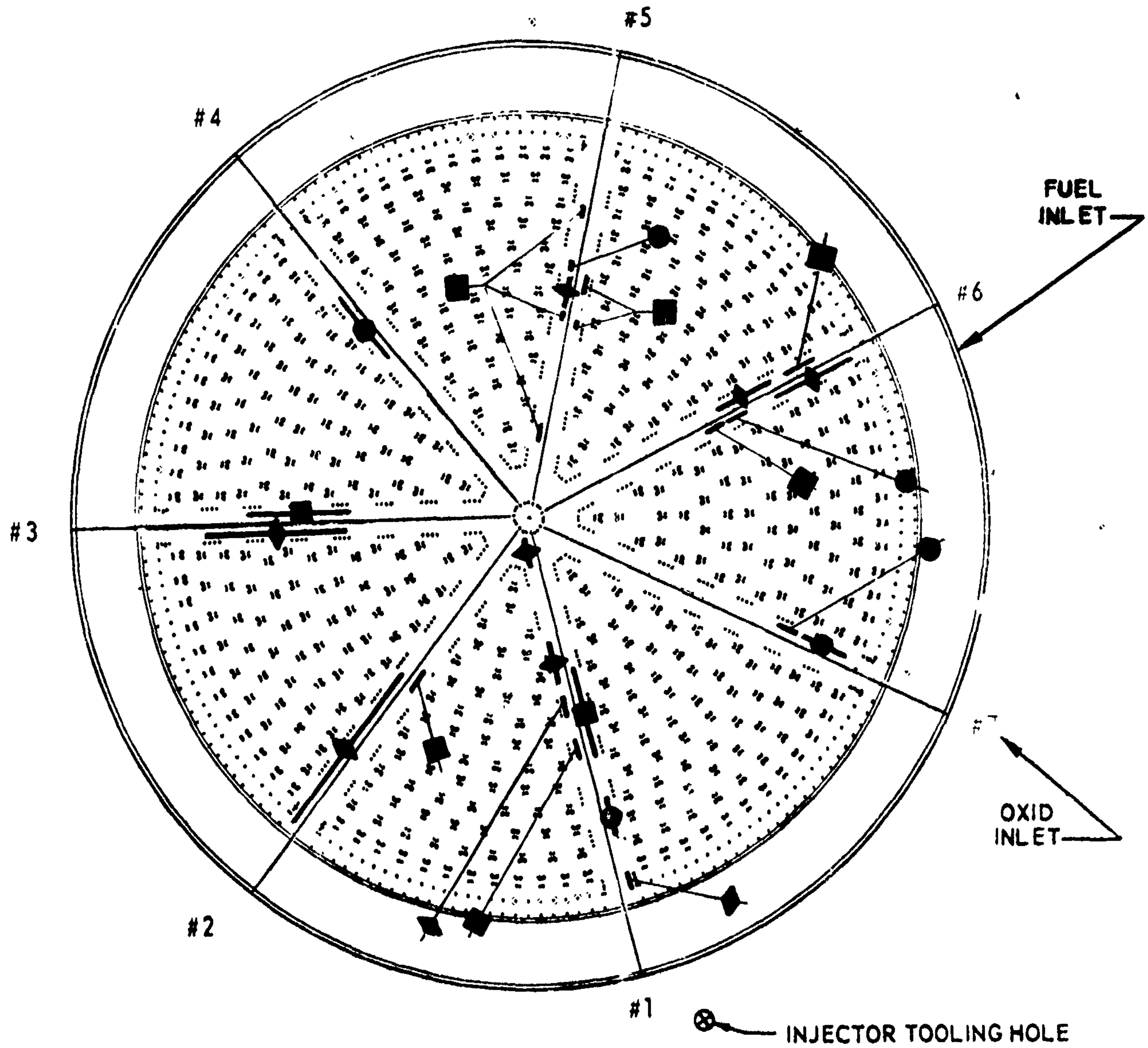
6, Discussion of Discrepancies (cont.)

6.2 THRUST CHAMBER ASSEMBLY

6.2.1 Injector Base Weld Cracks

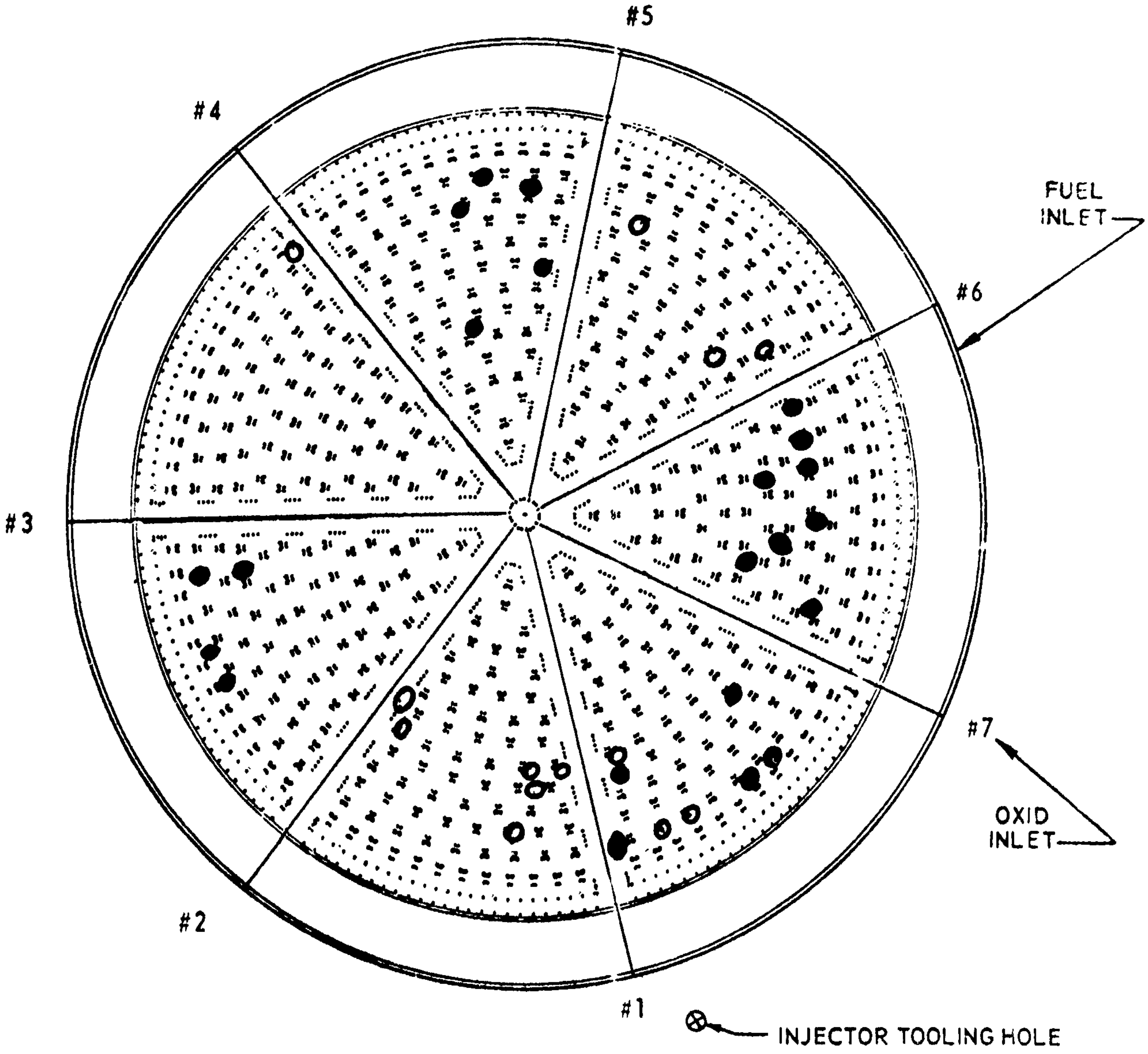
The post-test hardware inspections for Engine S/N 14 Test No. -204 and engine S/N 15, Test No. -303, (see Figure 69) revealed cracks in the base welds of several baffles in the injectors of both subassemblies. The cracks were through the base welds, thereby forming a leak path for the baffle coolant (oxidizer), and the baffle strength was reduced. Therefore the cracks were repaired after Test No. -204 and after subsequent tests, Nos. -206, and -208, on the Engine S/N 14 units to prevent damage to the thrust chamber hardware. New areas cracked on the successive tests, so after Test No. -208, all of the base welds were ground and rewelded to reduce instances of cracking in succeding tests. After Test No. -305, the units on engine S/N 15 were reworked by replacing all of the baffles in both injectors.

The cause of the weld cracking was determined to be an improper weld preparation and application. The base of the baffle legs was supposed to be beveled at a 45° angle to a depth of 0.060 inches. The fillet weld was supposed to fill this bevel, thereby forming a total fillet thickness greater than the baffle wall thickness. However, the bevel was less than 0.030 inches deep, and the thickness of the resulting fillet weld was slightly less than the thickness of the baffle wall. Also, the lack of weld penetration formed a discontinuity in the transmission of stresses from the baffle to the injector face, thereby increasing the bending stresses in the weld by 50% over what they would be with proper weld penetration. The resulting stress concentration and weak joint led to a premature fatigue failure at the weld joint.



● = Post Test #204
◆ = Post Test #206 } Dye Pen Results
■ = Post Test #208

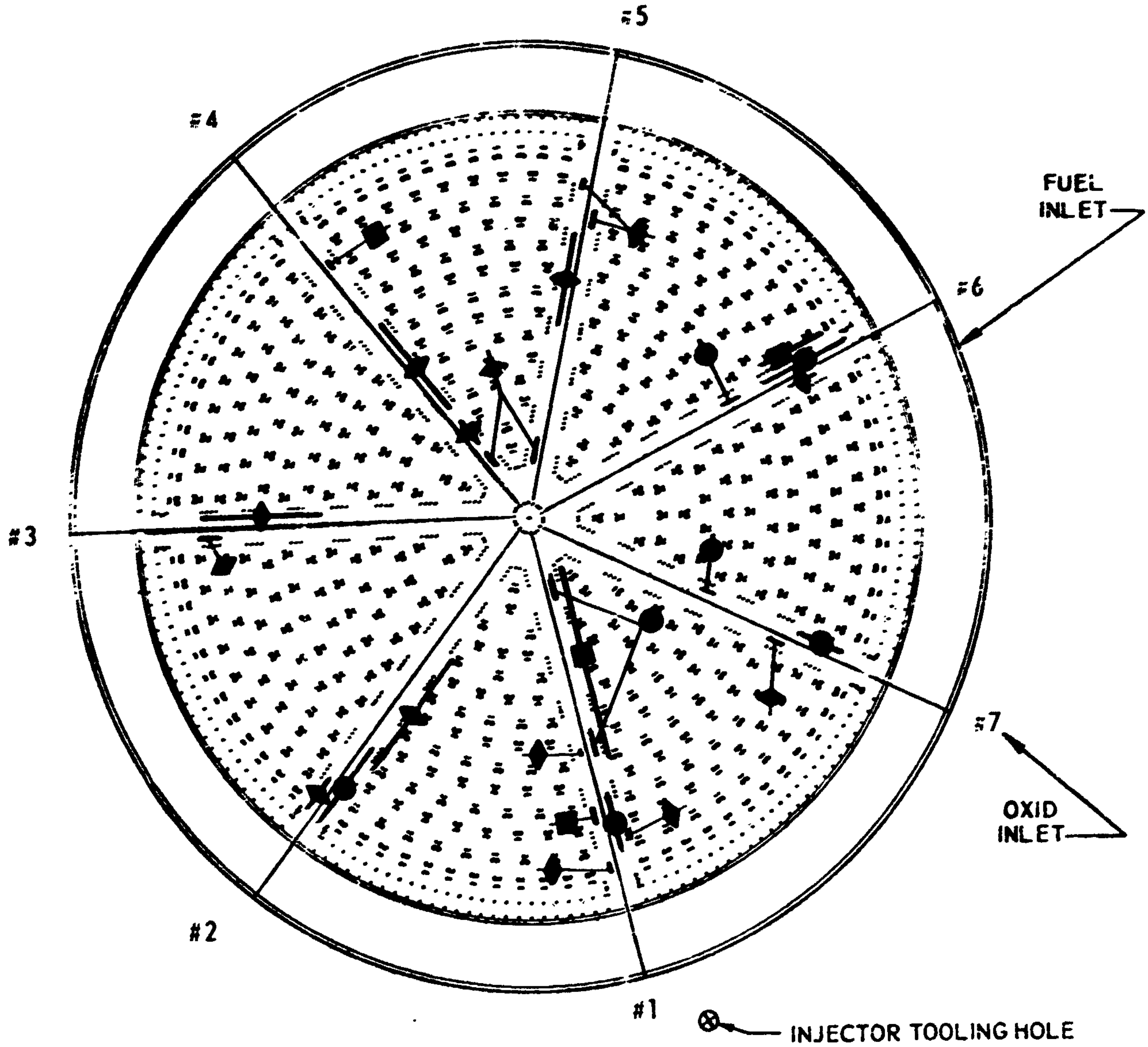
Figure 69--Location of Base Weld Cracks, Injector S/N 696, (1 of 2)



○ = Post Test #206 (Dye Pen Results, 13 Indications Total)

● = Post Test #208 (Dye Pen Results, 25 New Indications, 38 Total)

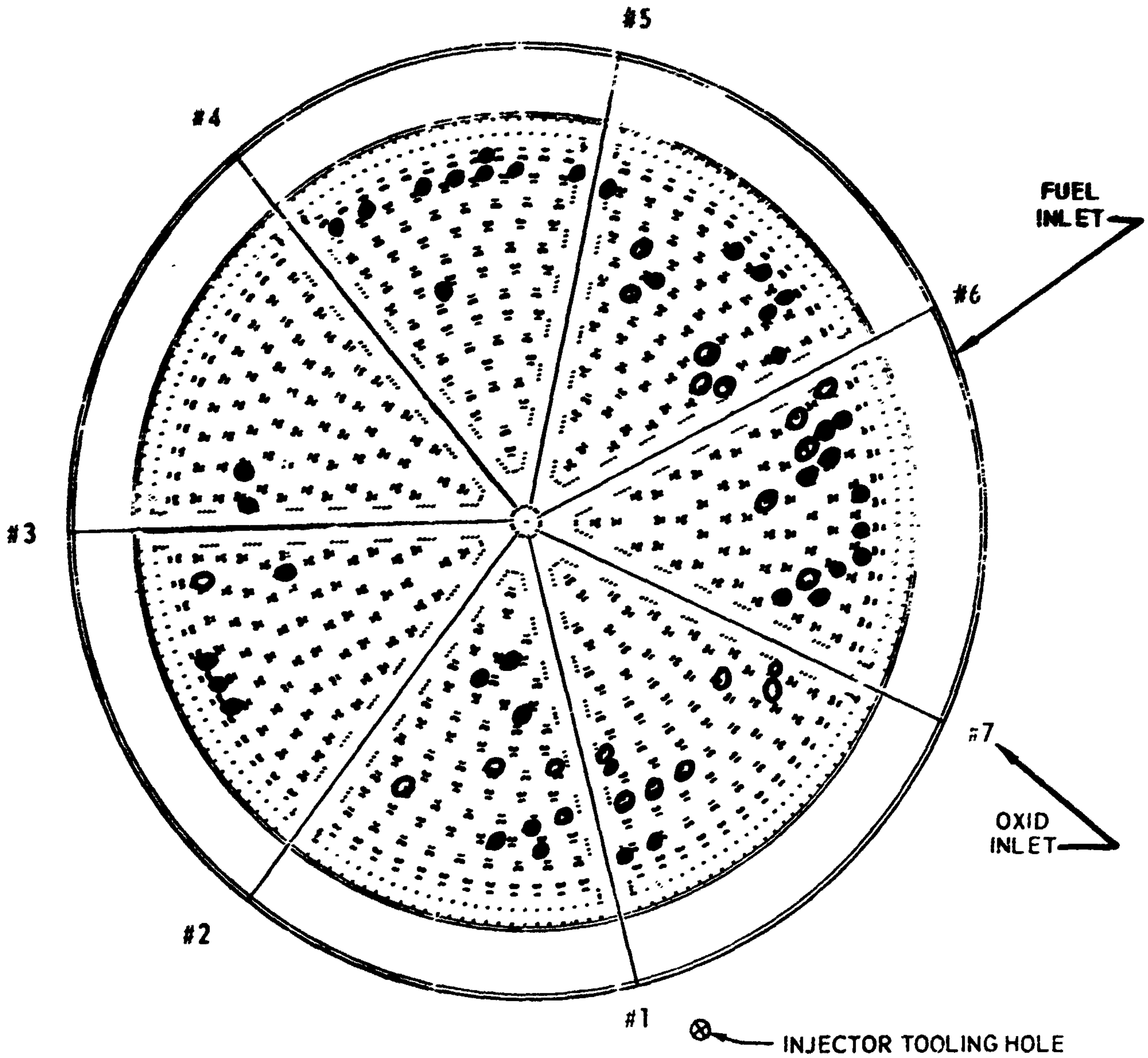
Figure 69--Location of Base Weld Cracks, Injector S/N 696 (2 of 2)



● = Post Test #204
◆ = Post Test #206
■ = Post Test #208

Dye Pen Results

Figure 69--Location of Base Weld Cracks, Injector S/N 697 (1 of 2)



○ = Post Test #206 (Dye Pen Results, 23 Indications)

● = Post Test #208 (Dye Pen Results, App. 40 New Indications)

Figure 69--Location of Base Weld Cracks, Injector S/N 697 (2 of 2)

).2, Thrust Chamber Assembly (cont.)

Corrective action was applied to the replacement baffles in the units on engine S/N 15 after Test No. -305 and all subsequent production injectors. The corrective action consisted of clarifying the dimensions of the baffle leg preparation and weld, and increasing the bevel angle to 60-70° for better access. This action provides for greater certainty that a full, penetrating weld is achieved.

As a result of the study of base weld cracks, the following conclusions were drawn:

(a) The subject base weld cracks were caused by improper joint preparation and weld application;

(b) The improper weld joint cracked because of concentrated stresses at a weak cross-section;

(c) A proper weld would not have cracked in the same time duration;

(d) The corrective action assures that a full, penetrating weld is achieved at the base of each baffle leg; and

(e) The repair procedure of grinding nearly through, then rewelding, provides a good structural joint that should survive 2-3 additional tests without failure.

In support of the conclusions, Figure 70 presents both the joint that was required for these units, and the actual configuration that was achieved. The actual weld is clearly inferior, causing a stress concentration that increases the local bending stresses by 50% and forms a minimum cross-sectional area. The failure occurred through fatigue of this joint after stress cycles caused by normal use.

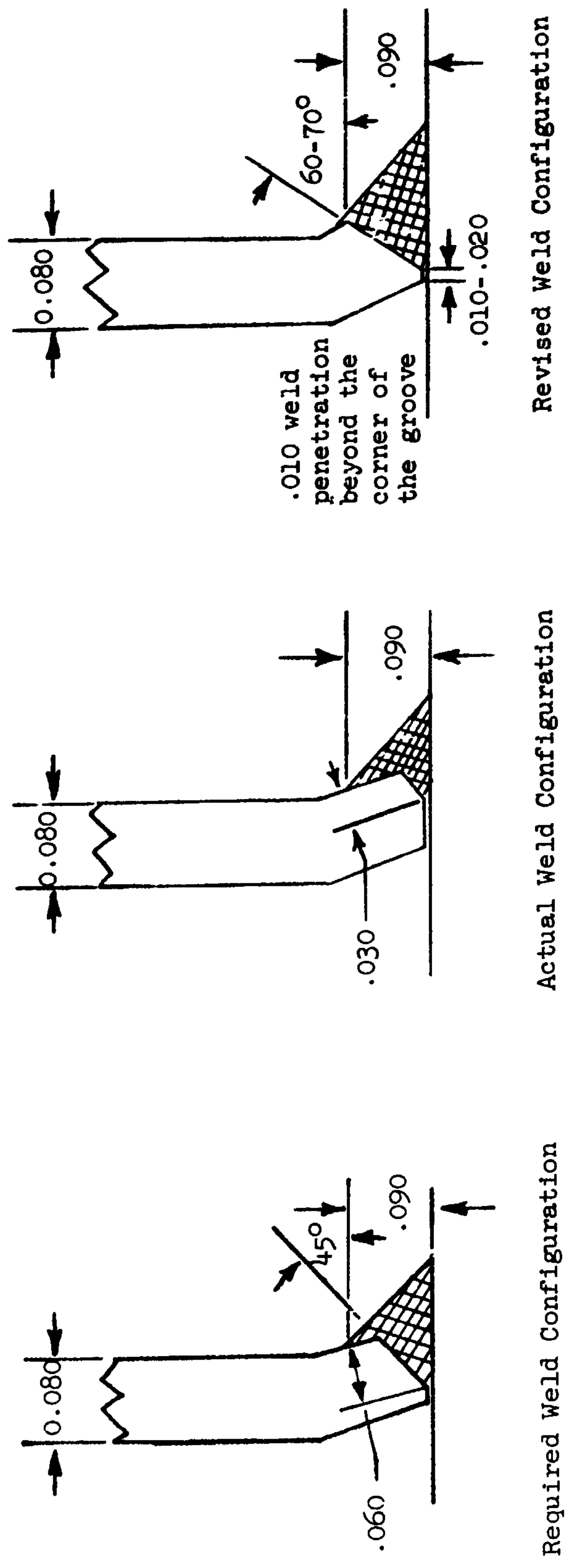


Figure 70--Baffle Base Weld Configurations

6.2, Thrust Chamber Assembly (cont.)

Figure 70c describes the revision requirements to effect a penetrating weld. The bevel angle was increased to 60-70° to afford better access for the welder, the depth of the bevel was dimensioned as a remaining land 0.010-0.020 inches thick for easy inspection, and the joint weld was revised to require a 0.010 inch penetration beyond the bottom of the groove. This penetration is not required for the strength of the joint, but the callout on the drawing tells the welder that a penetrating weld is desired, and he will not inadvertently bridge the groove rather than fill it.

6.2.2 Combustion Chamber Leaks

Forward Flange-to-Tube Joint

Leaks developed in the interior of three of the chambers during the demonstration testing. The leaks were all isolated to the forward flange-to-tube brazed joint and are the result of normal wear on chambers that were brazed prior to the advent of tighter controls on the brazing procedures to improve the chamber structure and brazed joints. The tighter controls achieve heavier, more uniform brazed joints at all brazed locations by minimizing the duration for which the chamber is heated above the liquidus point of the braze alloy. Also, the physical fitup of the tubes into the forward flange has been improved by swaging the ends of the tubes to the required diameter for optimum brazing.

The imperfect brazed joints resulted both from the inadequate physical preparation of the coolant tubes, such that the tubes fit too tightly into the flange holes, and a braze cycle that maintained the temperature of the chamber above the liquidus point of the braze alloy too long. The coolant tubes were inserted directly into the forward flange without supplemental swaging, and the total diametric clearance varied from 0.001 inch to zero.

6.2, Thrust Chamber Assembly (cont.)

This clearance is too small to effect a proper brazed joint with CM 62"B" alloy. These chambers were also brazed at a time when the total temperature range throughout the chamber was required to be less than 20°F. This was achieved by using a slow temperature rise rate above 1850°F up to a target of about 1950°F, and the result was that the chamber would be at temperatures above braze liquidus for periods of 25-30 minutes. During this extensive period, braze runoff would be excessive, and some "higher melt" constituents would form and fail to flow at all. Therefore the forward flange was joined to the chamber tubes with a lean, nonuniform brazed joint that failed prematurely under repeated pressure and temperature cycling.

As a result of the brazing study, the following specific changes were made to the brazing procedures:

(a) Swage the forward end of the coolant tubes to guarantee that a positive clearance of up to 0.004 inches exists between the tube and the insertion holes in the flange;

(b) Reduce the brazing time (time above braze liquidus) to less than 10 minutes;

(c) Bright-anneal the chambers prior to brazing to clean up the surfaces that are to be brazed; and

(d) Perform the brazing at lower temperatures than had previously been used with CM 62"B" alloy. Temperatures of 1920-1940°F are satisfactory to achieve good wetting yet retard runoff.

6.2, Thrust Chamber Assembly (cont.)

Coolant Tube Leaks

Two tube leaks were detected during engine postfire leak check activities.

Following Test No. -207 with engine S/N 14, Tube No. 28 in Chamber S/N 019 was found leaking at a rate of one drop per second. The leak was located four inches above the chamber throat and was not repaired prior to the following test. No investigation was conducted since the chamber was disqualified for other reasons and removed from the program after Test No. -208.

During the leak check of engine S/N 15 following Test No. -315, external tube leakage was detected through Tube No. 123 on chamber S/N 022. The leakage was located at a No. 1 V-fand-to-tube tack weld. The leak was repaired on the engine prior to the last test of the program. No investigation was conducted.

Forward Flange Cracks

Inspection of combustion chamber S/N 020 following Test No. -203 disclosed two small cracks in the forward flange. These cracks were about one-half inch long and ran longitudinally through the wall at the crown of the up-tube feed holes. The forward end of the cracks was located at the aft weld joint of the closure band, and the cracks extended aft short of the up-tube brazed area.

These cracks were a direct result of a weld repair operation that was performed during chamber fabrication. Prior to brazing, the chamber was assembled with a forward flange that had a defect in the closure band welds. The defect was not discovered until after the chamber had been brazed,

6.2, Thrust Chamber Assembly (cont.)

and a repair procedure was prescribed to remove the weld defect. The procedure called for grinding out the existing fore and aft weld areas with a V-shaped groove and rewelding using standard GTAW methods. However, the aft V-groove inadvertently cut into each up-tube passage, and residual braze within the passages contaminated the weld repair at the two crack locations. This residual braze material was identified and confirmed by X-ray.

The cracks are ascribed to the braze contamination of the weld because the X-rays show braze material only in the areas of the cracks. Cracking due to such contamination is commonly understood to result from the formation of intermetallic, brittle compounds during welding, and these compounds crack during thermal transients. The exact constituency of the brittle compounds is not known without metallurgical analysis or a theoretical study of the chemistry, but the manganese in the braze is presumed to be primarily involved.

No corrective action was applied because the primary weld procedure has been changed to obviate the need for extensive weld repair such as was necessary with the cracked chamber.

Coolant Tube Cracks

Two of the chambers developed cracks in the crowns of a coolant tube in the cylindrical section of the combustion chamber. Both cracks were found to be caused by the deposition of molten, metallic particles on the surface of the tubes. The particles evolved from slight erosions in the forward flanges directly in line with the cracked tube. The molten particles on the tube surface caused a momentary, excessive heat load, and carburization of the based metal was initiated. Local film boiling may have taken place,

6.2, Thrust Chamber Assembly (cont.)

but the film could not develop fully in such a restricted area. The molten particles also subjected the tube wall to excessive thermal stresses, and the cracks ensued.

Combustion Chamber Shell Cracks

A failure analysis was conducted to determine the cause for a crack in the weld joint at the shell, P/N 1130228 and the aft attaching ring, P/N 1129923, on combustion chamber S/N 092. This chamber was removed from Engine S/N 14 after Test No. -215 following 7 cycles and 865.06 seconds operation. Additionally, cracks were discovered in the weld joint at the shell to aft wire lock ring on Engine S/N 15 following Test No. -315. Five cracks had occurred on the shell lands on Subassembly 1 and on one land on Subassembly 2. Combustion chamber S/N 021 had experienced a total hot firing time of 1912.25 seconds over 14 cycles; combustion chamber S/N 022 performed 15 cycles for 1914.82 seconds. These cracks were repaired prior to Test No. -316.

A section of the shell was removed, including the cracked area of the weld, for analysis of mode-of-fracture. The replicated surface of the fracture was examined in the electron microscope. Ripple marks characteristic of fatigue caused by cyclic load were observed starting from the edge and extending down the fractured areas. The main fracture surface was indicative of cleavage and stress rupture (tensile). There were no dimples present, indicating a lack of ductility.

It was concluded that the fracture initiated in fatigue and rapid rupture was by cleavage and tensile mode. It was concluded further that improved welding practice will minimize the probability of crack recurrence at this location.

6.2, Thrust Chamber Assembly (cont.)

While the design of the J-groove is satisfactory, the provision for a "wrap-around" weld, starting on the side of the shell slot 90° from the shell land, will reduce the stress concentration point at the corner of the slot by permitting a smooth, continuous weld bead at the corner. The loading will be changed on the weld head terminal from tension to shear, which is advantageous in this application. This technique has proven successful in similar welding applications subjected to high cycle vibration.

Loose Wire Wrap

After the first test of engine S/N 14 the wirewrap on the divergent section of chamber S/N 020 was loose (see Figure 71). The loose strands started about 1 inch aft of the throat plane and extended over 2 inches of the nozzle length. Two additional tests were conducted with the loose wire. For the second of these tests the wire was taped in place to hold the wire in position during the start transient. The wire was removed after this test, but it was never replaced because the chamber was withdrawn from the test program.

During initial fabrication, the chamber had been wirewrapped twice in the forward section (forward of the throat plane), the second time because the wire was loose after final proof-and-leak testing had been completed. The wire in the aft section did not appear loose and was not similarly replaced. No specific cause for the loose wire in the forward section was ascertained, but it was noted that the surface of the wire was unclean. The wire was removed with little effort, and no adhesive forces existed between the wire and the Epon bed. Similarly, when the aft wirewrap was removed after loosening, the wire was found to be dirty.

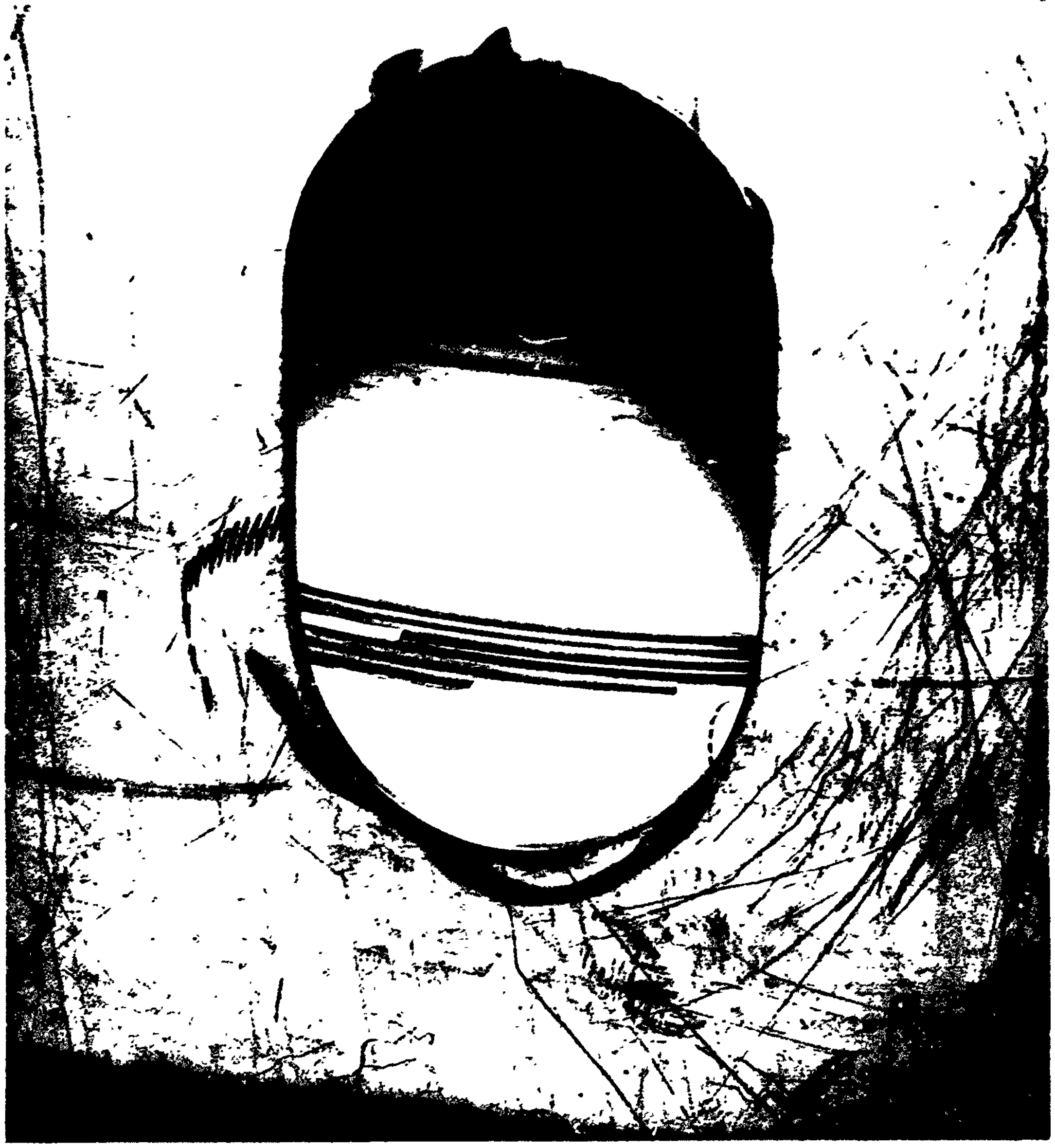


Figure 71 -- Loose Wire Wrap -- Chamber S/N 020

6.2, Thrust Chamber Assembly (cont.)

The looseness of the wire is not fully explainable, but it can be attributed to the same elements that caused the forward section of wirewrap to appear loose after proof testing. The cleanliness of the wire is believed to be important in maintaining wire tension through adhesion of the Epon bed to the wire. The corrective action provides for stripping both wire sections if either loosens during fabrication and for cleaning the wire to a degreased condition prior to and during wirewrap.

The corrective action was limited to adding cleaning operations to the wirewrap procedure and requiring that both wirewrap sections be stripped and replaced if either must be replaced. The cleaning consists of vapor-degreasing of the spool of wire in a hot atmosphere and, as the wire is wrapped, cleaning it with a cold degreasing agent applied to felt wipers on the wirewrapping machine. The wrapping procedure specifies the requirements for maintaining the felt pads at adequate effectiveness.

No further corrective action is required because loose wirewrap is anticipated in a low number of instances due to uncontrolled hand operation procedures. The final measure of the acceptability of a wirewrap is the prefire proof and leak test and the acceptance test. If the wirewrap appears loose after either of these tests, it can be easily replaced by proven procedures.

No corrective action was necessary since the damage was a random occurrence, unavoidable, acceptable, and easily repairable.

6.2, Thrust Chamber Assembly (cont.)

6.2.3 Gimbal Spacers, P/N 273736-1

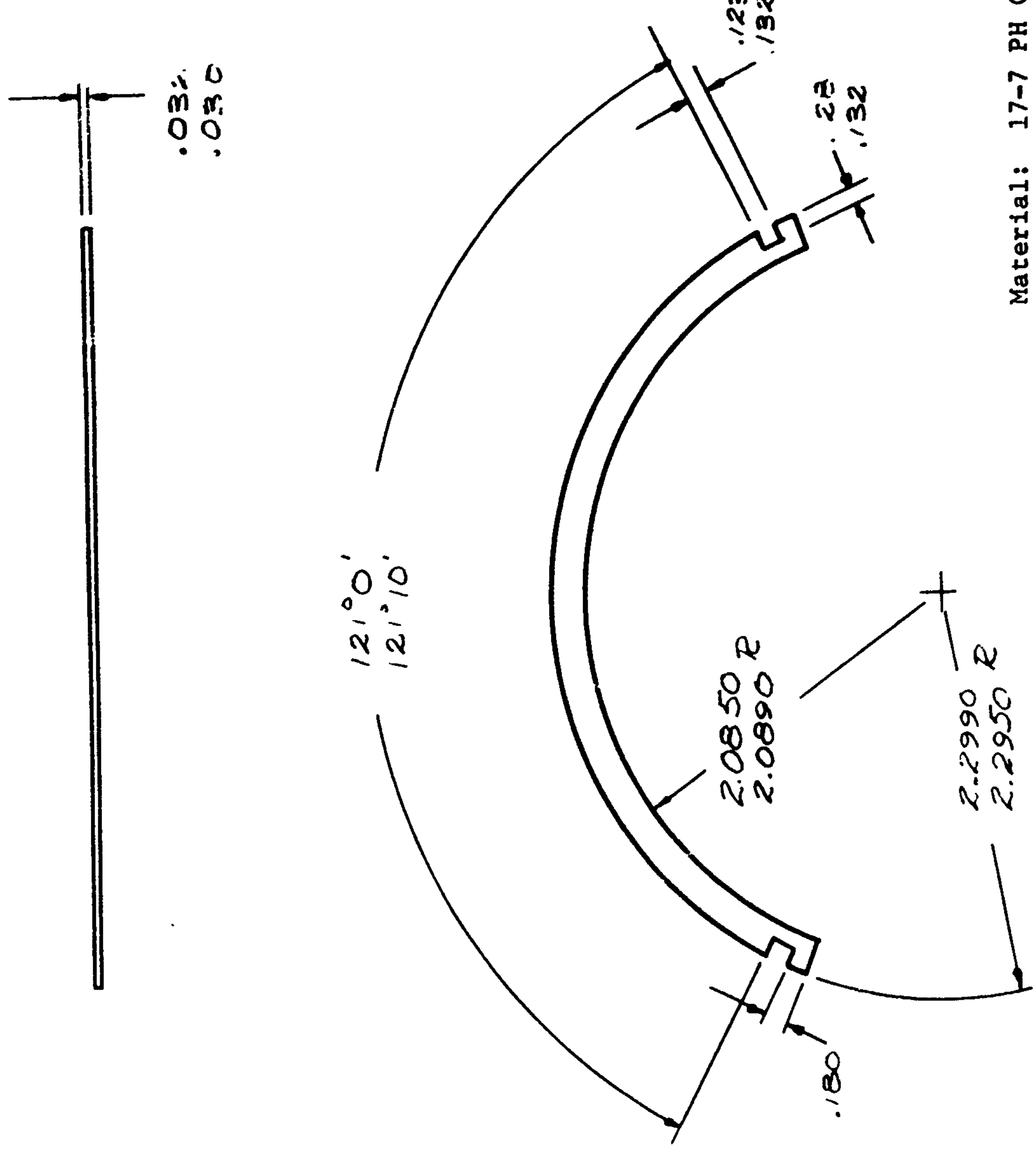
The Titan IIIM gimbal assembly contains ten spacers. Five spacers are used in the pitch bearing and the other five spacers are used in the yaw bearing. The function of the spacers is to separate the runs of roller bearings. The spacer used in the Titan IIIM gimbal assembly is shown in Figure 72. Five spacers along with two square rods from a bearing cage assembly which is moved during gimbal operation by a force applied to the square rod resulting from the progression of the roller bearings.

The spacer failure history of the four Demonstration gimbal assemblies is as follows:

Table 43 -- Bearing Spacer Failures

SN	Pitch Bearing	Yaw Bearing	Total
001	3	2	5
002	0	1	1
003	0	1	1
004	2	0	2

All spacer failures occurred at the corner of the square rod and were tensile type failures (see Figures 73 and 74). A high tensile load on the spacers can only occur when the spacer is restrained from progressing with the rollers. This restraint occurs when rollers become skewed, thereby forcing the spacer against the side of the spacer groove in the inner race. The detached spacer end is contained in the spacer groove by the gimbal lubricant which prevents it from wedging the roller bearings. No redesign activity is recommended at this time.



Material: 17-7 PH CRES

Figure 72--Gimbal Roller Spacer, P/N 273736-1

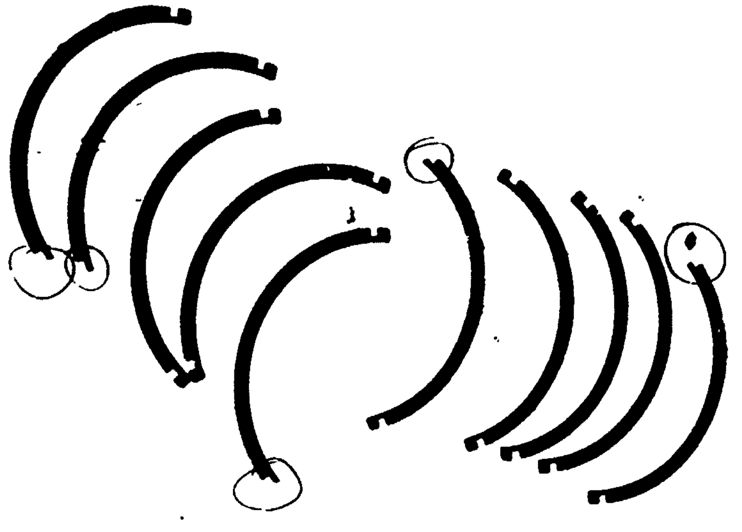


Figure 73 -- Bearing Spacer -- S/N 477

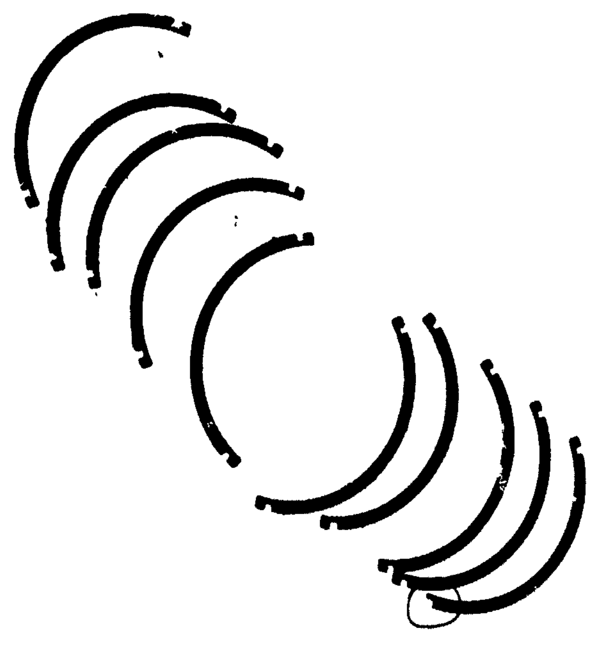


Figure 74 -- Bearing Spacer -- S/N 478

6, Discussion of Discrepancies (cont.)

6.3 TURBOPUMP ASSEMBLY

6.3.1 First Stage Rotor

Test No. -204 (engine S/N 14) was terminated at FS1 + 115.938 seconds because of failure of the first stage rotor of TPA S/N 010 on Subassembly 2. The rotor was of the cast-blade configuration, P/N 1130983-3, which was being used in the interim while the prototype 83-blade Waspalloy rotor was unavailable.

The failure was classified as a blade root crack, which had previously been determined to be the cause of several previous failures of the cast-blade rotor configuration. For this reason an attempt was made to retire the rotors from service before critical cracking had occurred. After each test, the number and length of root cracks were determined by inspection and recorded. Prior to the test during which it failed the rotor had 57 cracks, the longest two being 0.120 inch in length.

The damaged condition of the rotor precluded identification of the exact blade which initiated the failure. As with previous failures of the cast-blade rotor, no indication of an impending failure was observed from the test data. A review of the accelerometer data indicated normal amplitudes prior to failure. At FS2-1.3 seconds all accelerometers responded by an instantaneous acceleration spike to as high as 100 g rms.

Following this failure the use of cast-blade rotors was discontinued on the Titan IIIM program and testing was continued using the prototype rotors of the integral blade design, which have proven to be highly reliable.

6.3, Turbopump Assembly (cont.)

6.3.2 Oxidizer Pump Seal Anomaly

Subsequent to Test No. -307 with engine S/N 15, "straight-through" oxidizer pump seal leakage was observed from both subassemblies. Three additional tests of 224 sec cumulative duration were conducted after the leakage was discovered.* On disassembly, the carbon nose piece on both seals (P/N 291377-19, S/N 1350, Subassembly 1 TPA and S/N 1348, Subassembly 2 TPA) was found to be fractured into numerous pieces.

Inspection of the seal assemblies disclosed no unexpected irregularities. The spring compression rate of the bellows was somewhat weak at the 18-lb load on each seal, and parallelism varied from 0.006 to 0.015 in. in the free state. A 10-psig Freon leak check indicated no fracture in the bellows material or at the weld attach points. The oxidizer impeller back vane clearance on the two TPA's from engine S/N 15 compared favorably with those of engine S/N 14:

	S/N 15 Oxidizer Backvane Clearance	S/N 14 Oxidizer Backvane Clearance
Subassembly 1	TPA S/N 009 - 0.030 in.	TPA S/N 008 - 0.030 in.
Subassembly 2	TPA S/N 011 - 0.026 in.	TPA S/N 006 - 0.027 in.

Test data were reviewed for comparison of the magnitude and duration of the low NPSH test with engine S/N 14, which revealed essentially no leakage posttest, with the NPSH test of engine S/N 15 resulting in straight-through pump seal leakage, posttest, on both subassemblies. It is significant to note that the low NPSH test of engine S/N 14 was conducted at 15.5 ft suction head (average of both subassemblies) below the 44 ft NPSH specification minimum limit for 55 sec duration. In contrast, the low NPSH excursion on

*With AF approval. There was no serious hazard, and the engine was scheduled for return to the Manufacturing Area.

6.3, Turbopump Assembly (cont.)

engine S/N 15 was conducted at an average subassembly suction head of 25.5 ft below the minimum NPSH limit for an average duration of 64.5 sec.

Search of the test records revealed no evidence of previous testing in a pressure range lower than 23 ft suction head. It appeared possible that an analysis of accelerometer data of both normal and the low NPSH tests on both demonstration engines could help to determine if the unusually low NPSH condition during Test -307, with attendant cavitation, caused an increase in vibration that could be identified as reason for the carbon seal failure.

The vibration data were spectrally analyzed from 0 to 4800 cps in 100 cps bandwidths with 2-sec averaging intervals. The vibration level was low, particularly at the lower frequencies. In addition, the vibration data were spectrally reviewed in the 20 cps bandwidths from 0 to 1000 cps for each 0.5 sec time interval. The data were analyzed with specific emphasis on identifying any increase in vibration during the period of low NPSH. No difference in level could be observed within the run, nor was there a significant difference in vibration noted between the normal and the low NPSH tests. The variation in any of the vibration data is considered to be within the spread of normally operating turbopumps.

While the accelerometer data is inconclusive, the lack of further substantiating data does not alter the conclusion that a combination of forces, hydraulic and vibrational, occur during operation in a pressure area below 23 ft of suction head sufficient to impact the carbon nosepiece beyond its stress limits. Since the TPA is not operated at the low NPSH which caused the discrepancy, and since the discrepancy was not major, a recommendation for further action was considered unnecessary.

6.3, Turbopump Assembly (cont.)

6.3.3 Fuel Pump Seal Leakage

Postfire inspection following Test No. -316 with engine S/N 15 revealed that the fuel pump seal, S/N 1353, TPA S/N 009, Subassembly 1, was leaking at a rate too great to measure by normal inspection methods. The seal was removed from the turbopump for further evaluation, which disclosed that the leakage was through the bellows rather than across the carbon sealing face. A fracture had occurred approximately two inches long adjacent to the weld on the third bellows convolution.

Review of motion picture films disclosed that the leakage commenced at approximately FS1 + 3 seconds, increasing in magnitude throughout the test until finally a steady stream of fuel was flowing from the cavity drain at the end of the test. The fuel pump leakage was not reflected in the test data and did not affect performance.

The bellows portion of the seal was sectioned thru the fracture area and subjected to fractograph analysis. While it was impracticable to analyze the full 2 in. length of the crack, sufficient information was obtained to infer that the mode of failure was fatigue. The material structure was satisfactory.

Fuel pump seal S/N 1353 had experienced 2120 seconds during 16 cycles of operation prior to failure of the seal. The flexing of the bellows over an extended period of time induces cyclic stresses which, under severe demonstration testing, resulted in fatigue failure. It is not expected that these circumstances will occur under production engine duration requirements.

6.3, Turbopump Assembly (cont.)

No further action is recommended. While there was evidence that fuel had leaked past the gearbox seal and into the gearbox, no loss of performance or damage to the TPA resulted during test because of the leakage. This discrepancy is considered to have no potential impact on the ability of the turbopump to complete acceptance or flight tests.

6.3.4 Turbine Seal Leakage

Posttest inspections following Test No. -305 with engine S/N 15 revealed that the turbine seal, S/N 4869, of TPA S/N 011, Subassembly 2, had a leakage rate of 1200 cc/min. The turbopump was removed from the engine for inspection of the turbine seal and for rework.

Rework of the turbine seal to correct the leakage consisted of lapping the carbon nosepiece of the turbine seal and also the rotating ring to drawing requirements. The only item replaced was the Teflon O-ring which seals the rotating ring at the shaft.

A review of the turbopump data from Test No. -305 revealed that the turbine seal started to leak at start of the test. The parameter which reflects this anomaly is the gearbox pressure which began to increase at the start of the test, and increased to a maximum of 17 psig at FS1 + 60 sec. From FS1 + 60 sec to FS2, the pressure remained at approximately 17 psig, indicating that the gearbox relief valve was venting the additional flow of the hot gas from the gearbox. No other parameters showed any anomalous characteristics because of the turbine seal leakage.

At the time that the excessive leakage was discovered, the seal had been subjected to five tests for an accumulated test duration of 823.5 sec. No other hardware damage resulted from the turbine seal leakage, and the

6.3, Turbopump Assembly (cont.)

leakage had no effect on engine operation or performance. Following the rework the seal was satisfactorily subjected to another 11 tests for 1291.2 sec additional accumulated test time. Turbine seal leakage of this magnitude after five tests and 823.5 sec operation is not considered to be serious and has no impact on the reliability of the turbopump.

6.3.5 Loose Rotor Bolt

During the posttest disassembly of the turbine kit of TPA S/N 010 following Test No. -203 with engine S/N 14, the turbine rotor retaining bolt was found to have lost all preload. This bolt is preloaded during assembly to ensure proper operation of the curvic couplings. This was the first occurrence of complete preload loss in over 80 TPA and engine tests.

An investigative program was conducted to determine the cause of the preload anomaly and considered the following:

(a) Yield strength of the rotor bolt material.

(b) Inspection of the curvic coupling surfaces for possible yielding, fretting or other indications of distress.

(c) Review of the turbine kit assembly procedures and techniques.

(d) Inspection of the rotor bolt and input shaft threads for damage.

(e) Structural deformation of the shaft, rotors and bolt.

(f) Hardware history and test data to indicate when the anomaly occurred and what events may have led to its cause.

TPA S/N 010 had been installed on Subassembly 2 of engine S/N 14 for a 20-sec adjustment test (No. -201) and used "workhorse" rotors. No change in bolt elongation was noted during the postfire inspection. The "workhorse" rotors were replaced with Demonstration rotors S/N 624 and S/N 003. Rotor bolt P/N 1130976-19 was replaced with bolt P/N 1130976-29 which features a

6.3, Turbopump Assembly (cont.)

pilot with 0.005 in. clearance in the first stage rotor bore. Subsequently engine Test No. -202 was conducted satisfactorily for 200 sec duration. Postfire rotor bolt elongation measured 0.0085 in. as compared to the initial assembly elongation of 0.009 in.

First and second stage rotors S/N 638 and S/N 008 were then installed in TPA S/N 010; no other changes were made on the TPA. Test No. -203 was conducted satisfactorily for 200 sec duration. The loss of preload on the rotor bolt was discovered during the postfire turbine kit disassembly for inspection.

It is expected that an unloaded rotor bolt would result in improper alignment of the curvic coupling and imbalance of the high speed shaft turbine rotor assembly. The data considered in the evaluation of the high speed shaft imbalance are the bearing temperatures and the gearbox acceleration levels.

The shaft bearing temperatures of the subject test are compared to the same measurements from the previous test:

	-202	-203 (Loose Bolt)
Bearing 4, TB-4	165°F	172°F
Bearing 5, TB-5	207°F	215°F
Bearing 6, TB-6	292°F	300°F

The bearing temperatures from the test with the unloaded bolt were slightly higher than those of the previous test; however, they were well within the variation expected between the two tests.

A review of the acceleration data showed no distinctive occurrence or change in vibration amplitude which could be associated with unusual imbalance. However, only gross imbalances are reflected by the accelerometer data as

6.3, Turbopump Assembly (cont.)

instrumented for this test. For example, during a TPA test in which two rotor blades separated from the first-stage rotor, the change in vibration characteristics was barely perceptible.

The first rotor was heavily coated with lube oil as a result of the turbine seal leak. Also noted during the inspection was a light rub on the hub adjacent to the heat shield. The heat shield, however, did not exhibit evidence of a rub. Of special note was the contact pattern of the Curvic coupling; it was apparent that contact was heavier on the driving side of the teeth than it was on the non-driving side. Normally the contact pattern is nearly identical for the driving and non-driving sides.

The second rotor was also heavily coated with lube oil. In addition, excess Fel-Pro C5-A Anti-Seize Compound was found adjacent to the seat of the retaining bolt head. A large quantity of this anti-seize compound is normally used at this location; however, most of it is squeezed from the interface during the torquing operation of the rotor bolt.

The shaft, like the first rotor, exhibited the unusual contact pattern on the Curvic coupling teeth. The internal thread of the shaft was inspected by casting impression using a catalytic setting synthetic rubber compound. Impressions of a new shaft were compared with impressions from a shaft used during nine TPA tests. An optical comparator was used to analyze the impressions. The inspection of the subject shaft thread did not reveal any anomalous conditions which would cause the loss of preload.

The retaining bolt was inspected for hardness and composition. Analysis of the composition verified that the material was Alloy 718. Hardness of the bolt was determined to be RC 36. The minimum hardness as specified by the heat treat specification is Brinell Hardness Number 352 (Equiv. RC 38). The thread form of the bolt was inspected on an optical

6.3, Turbopump Assembly (cont.)

comparator and found to be satisfactory. The underneath side of the rotor bolt head had a heavy coat of Fel-Pro C5-A. The presence of a large quantity of this material is considered unusual. Normally, it is extruded from the rotor-bolt head interface during assembly.

The most probable cause for the preload loss is incorrect preloading of the turbine rotor retaining bolt during turbine-kit assembly.

After the investigation for the cause of the preload loss, TPA S/N 010 was reassembled. The turbine-kit was assembled with all of the original components including the bolt. The TPA was then installed on engine S/N 014 and tested. The purpose of assembling and testing the TPA with the original components was to demonstrate that the preload loss was not associated with any of the turbine-kit components. The test, No. -204, was scheduled for 200-sec duriation but was terminated after 115 sec duration because of failure of the first stage turbine rotor. The cause of the failure has been attributed to cracks in the blade.

Initial assembly preload of the bolt was 0.009 in. and at posttest it was 0.0085 in. Since there was no significant change in bolt preload, it can be concluded that the original preload loss was not caused by a marginal condition or component in the design. The difference between pretest and posttest preload is within the expected variation between two measurements. The rotor failure is considered not to have affected the preload. The above information substantiates the conclusion that the absence of the preload after the test was actually reflecting the lack of initial preload.

6.3.6 Corroded Bearings

At the time of the formal display of engine S/N 15 the upper roller and center ball bearings of the fuel shaft of TPA S/N 009 were found to be

6.3, Turbopump Assembly (cont.)

stained (see Figures 75 through 80). This condition had not been observed, however, when the turbopump was disassembled approximately four weeks earlier. For this reason it is concluded that the staining occurred following the disassembly when the parts were exposed to the atmosphere. This is substantiated by the fact that the staining occurred in areas where the rolling elements contacted the races while at rest. In accordance with the display preparation the parts were retained in the as-is condition; that is they were not cleaned or protected with preservative.

The inspection procedures during turbopump disassembly revealed that gross leakage of the fuel pump seal was due to a failed bellows. A review of the motion pictures of the last test show that the seal began to leak a few seconds following the start of the test, and increased in leakage during the test so that a steady stream of fuel was flowing from the overboard drain at shutdown. In spite of the gross leakage the seal cavity was found to be relatively clean. Some evidence of foreign material was observed at the gearbox seal rotating ring locknut; however, this location is outboard of the gearbox seal sealing face. During the disassembly it appeared that the gearbox seal had prevented the entry of contaminants into the gearbox. However, in view of the stained condition of the fuel shaft bearings, it is concluded that either fuel or fuel neutralizer entered the gearbox by passing through the failed fuel pump seal bellows, and then through the gearbox seal and into the gearbox. As stated previously no attempt had been made to clean, decontaminate or neutralize any of the turbopump components on disassembly. The presence of contaminants would have been detected had the normal turbopump handling procedures been used. These procedures include the removal of the pump and gearbox dynamic seals for cleaning and neutralizing of the seals and cavities. The areas inboard of the gearbox seals are checked for the presence of propellant and propellant neutralizers by a pHydrion test.

Figure 75 -- Bearing B-10, S/N 1462 -- Inner Races

Figure 76 -- Bearing B-10, S/N 1462 -- Balls and Cage

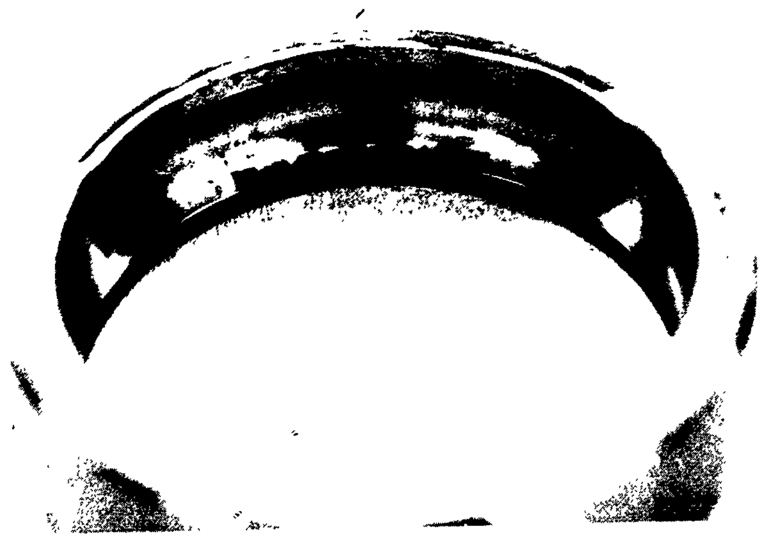


Figure 77 -- Bearing B-10, S/N 1462 -- Outer Race

Figure 78 -- Bearing B-9, S/N 1450 -- Outer Race

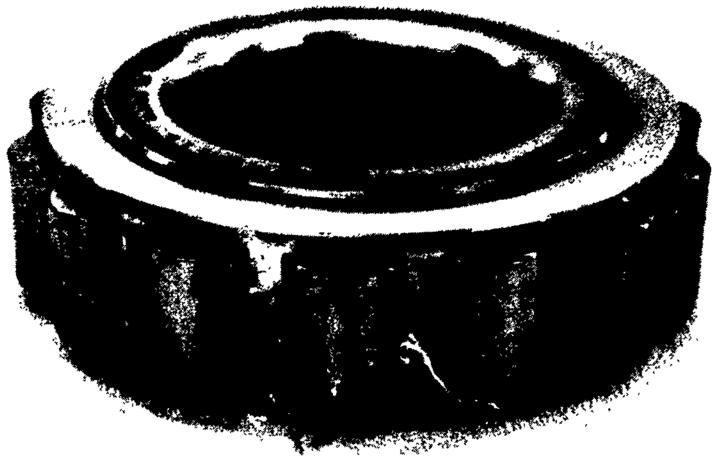


Figure 79 -- Bearing B-9, S/N 1450 -- Inner Race, Cage, and Rollers

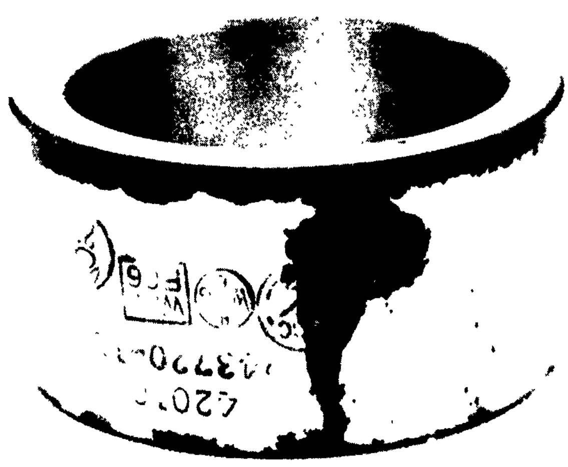


Figure 80 -- Spacer -- Bearing B-9/Bearing B-10

6.3, Turbopump Assembly (cont.)

The existence of contamination inboard of the gearbox seals requires that special cleaning procedures be initiated. The subject bearing damage would have been prevented had not the requirements for engine review supererogated the appropriate cleaning procedures.

6, Discussion of Discrepancies (cont.)

6.4 ENGINE CONTROLS

6.4.1 PSVOR Malfunction

Subassembly 1 of engine S/N 15 failed to start during Test No. -309. Posttest investigation located the problem at the pressure sequencing valve, S/N 640. Further analysis revealed that the failure of PSV S/N 640 to actuate the thrust chamber valves was caused by failure of the override solenoid (PSVOR), S/N 2437, which remained in the energized or actuated position after the prefire electrical check of the start cartridge.

The cause of the PSVOR failure was the presence of foreign material in the solenoid core cavity between the plunger and bore. This substance was of sufficient viscosity and adhesion to overcome the load on the small (6-lb rate) spring, thus preventing the return of the valve mechanism to the de-energized position.

Material analysis revealed that a polyester-styrene copolymer coating is applied to the laminated shims located between the end of the solenoid core housing and the movable plunger. This coating or film is partially soluble in AeroZINE 50 and methyl alcohol. The resulting gummy substance can be dispersed in the solenoid cavity, and if deposited between the plunger and core walls can provide sufficient adhesion to prevent return of the valve mechanism to the de-energized position.

The mode of failure, concluded to be random in nature on the basis of the recorded failure-free history of the PSV, is however, of sufficient gravity to warrant implementation of corrective action. The PSVOR is being modified by the supplier, Weston Hydraulics (their P/N 33215) to provide a selection of one of four uncoated shims of variable thickness to be used at

6.4, Engine Controls (cont.)

assembly to attain the required 0.003 to 0.005 in. air-gap dimension. This change is currently being processed by ECP and will be finally reflected in a PSV part number change.

6.4.2 Controls Harness Assembly

An investigation of a below average value of insulation resistance in the controls harness for engine S/N 14 (Ref. IR 463597) revealed that one of the PSVOR leads was at fault. The problem was traced to a flaw in the insulation of the lead between the diode assembly and the interface connector in the interface junction box assembly. During assembly of this box, the lead had become trapped between a connector mounting boss on the cover and the diode assembly package. Tightening of the cover hold-down screws had exerted a constant pressure on the lead wire which resulted in cold flowing of the Teflon insulation. The time between assembly and failure was approximately two months.

It is recommended that the cover of the box be changed to machine the connector mounting bosses on the outside to prevent a possible recurrence of this type of problem.

6.4.3 Thrust Chamber Oxidizer Valve Lipseal

Lipseal S/N 0010006 was removed from TCOV S/N 606 of Subassembly 1 after Test No. -214 with engine S/N 14 after 14 engine tests for a total duration of 1645 seconds. The engine was cleaned three times during the intervening seven months and 14 tests.

6.4, Engine Controls (cont.)

Lipseal S/N 0010008 was removed from TCOV S/N 604 of Subassembly 2 after Test No. -215 with engine S/N 14. The lipseal was on the engine for approximately one week prior to Test No. -215; it was purged after the test and then decontaminated one week later. Total accumulated engine test time for this lipseal was 200 seconds and one test firing.

Lipseal S/N 0010009 replaced lipseal S/N 0010006 in TCOV S/N 607 for one 200 sec test, No. -215, the last with engine S/N 14. This lipseal was exposed to the same environment as lipseal S/N 0010008.

The material from which the oxidizer lipseals S/N 0010006, S/N 0010008 and S/N 0010009 were made was certified based on samples that were tested on 5 April 1966. Seals Serial Nos. 0009999 thru 0010015 were delivered on 21 April 1966 as a part of Lot No. 529. Material for Lot No. 529 was certified to be Kel-F 81-6061. The specific gravity of the material was between 2.139 and 2.141 which is the upper limit of the specification AGC-44028 requirement of 2.11 to 2.14. The hardness was 9.662 Knoop Average in an allowable range of 9.2 to 10.4. The only questionable item is the excessive elongation at yield stress which was 18% average with a specification minimum of 7.8%.

Seals S/N 0010006, S/N 0010008, and S/N 0010009 were analyzed after they were removed from engine S/N 14. There were intermittent circumferential flexural stress cracks in the bend area of seal S/N 0010006 which were initiated at the downstream surface and were approximately one-third through the lipseal thickness (see Figure 81). The lipseal material (CTFE) had a slight to moderate yellow green tinge. Five hardness readings taken were 8.7, 8.6, 8.6, 8.8 and 9.0.

There were connecting circumferential flexural stress cracks in the bend area of seal S/N 0010008 which were initiated at the downstream surface,

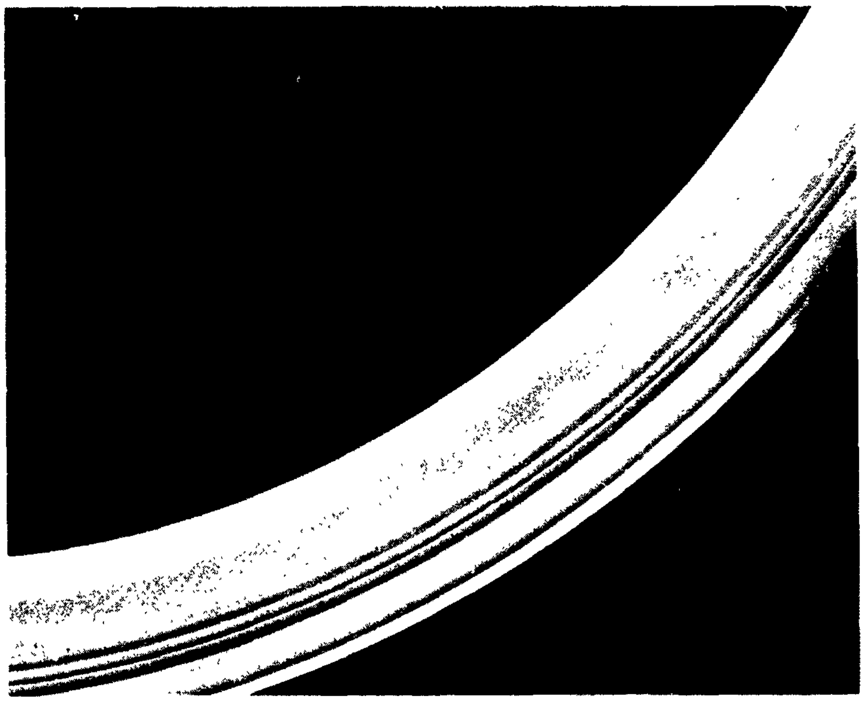


Figure 81 -- Lip Seal -- S/N 0010006

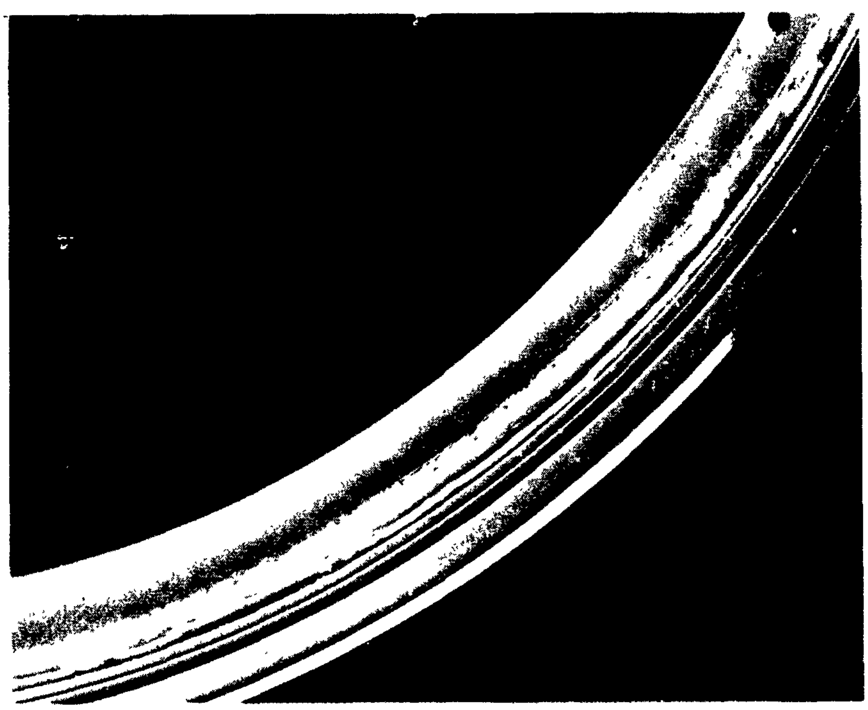


Figure 82 -- Lip Seal -- S/N 0010008

6.4, Engine Controls (cont.)

and approximately thirty percent of the cracking was all the way through the lipseal thickness (see Figure 82). The lipseal material (CTFE) had a slight yellow tinge. Five hardness readings taken were 8.9, 8.9, 8.7, 8.4 and 8.2.

Lipseal S/N 0010009 had no apparent in-service damage. The lipseal material (CTFE) had a slight yellow tint. Five hardness readings taken were 10.0, 9.3, 9.4, 9.4 and 9.3.

Previous laboratory evaluations of Kel-F 81 have shown that after 24 hours soaking in N_2O_4 the material hardness decreases by 50%. The hardness recovers to within 2% of its original value after 10 days exposure to air and to within 1% of its original value after 18 days in air. The hardness tests of lipseals S/N 0010006, S/N 0010008, and S/N 0010009 were performed approximately 90 days after removal from the engine.

The low hardness of lipseals S/N 0010006 and S/N 0010008 disclosed that they were of a relatively low crystallinity, and consequently, had lower strength. The low hardness of these two lipseals could also be an indication of incomplete annealling; thus the seals would retain relatively high internal stresses. The low strength and high internal stresses may account for premature stress cracking.

Dimensional checks were also made on the lipseals. The inside diameters on lipseals S/N 0010006 and S/N 0010009 are less than the minimum print tolerances. Lipseal S/N 0010008 is on the lower side of the print limit. Since inservice experience shows an increase in this dimension due to the stretching on the gate, it can be surmised that the material must have shrunk, since the parts were in tolerance on inspection at receipt prior to assembly. This substantiates to some degree that the material may not have been properly annealled.

6.4, Engine Controls (cont.)

No change in lipseal design is planned at this time.

6.4.4 TCOV Bearing Liner, P/N 708630-1

One bearing liner S/N 3337 from TCOV S/N 605 was found loose and partially folded over upon itself (see Figure 83). Probably insufficient lubricant to the shaft and bearing ID and possibly a sharp edge of the shaft caused the damage to the liner during valve assembly. No design change in bearing configuration is planned at this time.

6.4.5 Turbine Speed Probe

Turbine speed could not be monitored during Test No. -302. Postfire checks revealed that there was an open circuit in probe P/N 1133478, S/N 764 (Vendor C.E.C. S/N 1044). The probe was returned to the vendor for examination and analysis. The vendor reported the output of coil B met specifications 1.5 to 5 volts. There was no output from coil A. Difficulty was encountered in opening the unit to determine cause of failure due to its hard potting construction; therefore, the exact cause of the open circuit could not be determined.

Experience reveals that the N_T probe is a reliable unit which may rarely experience failure. No design change is anticipated and faulty units will be replaced. No further action is warranted.

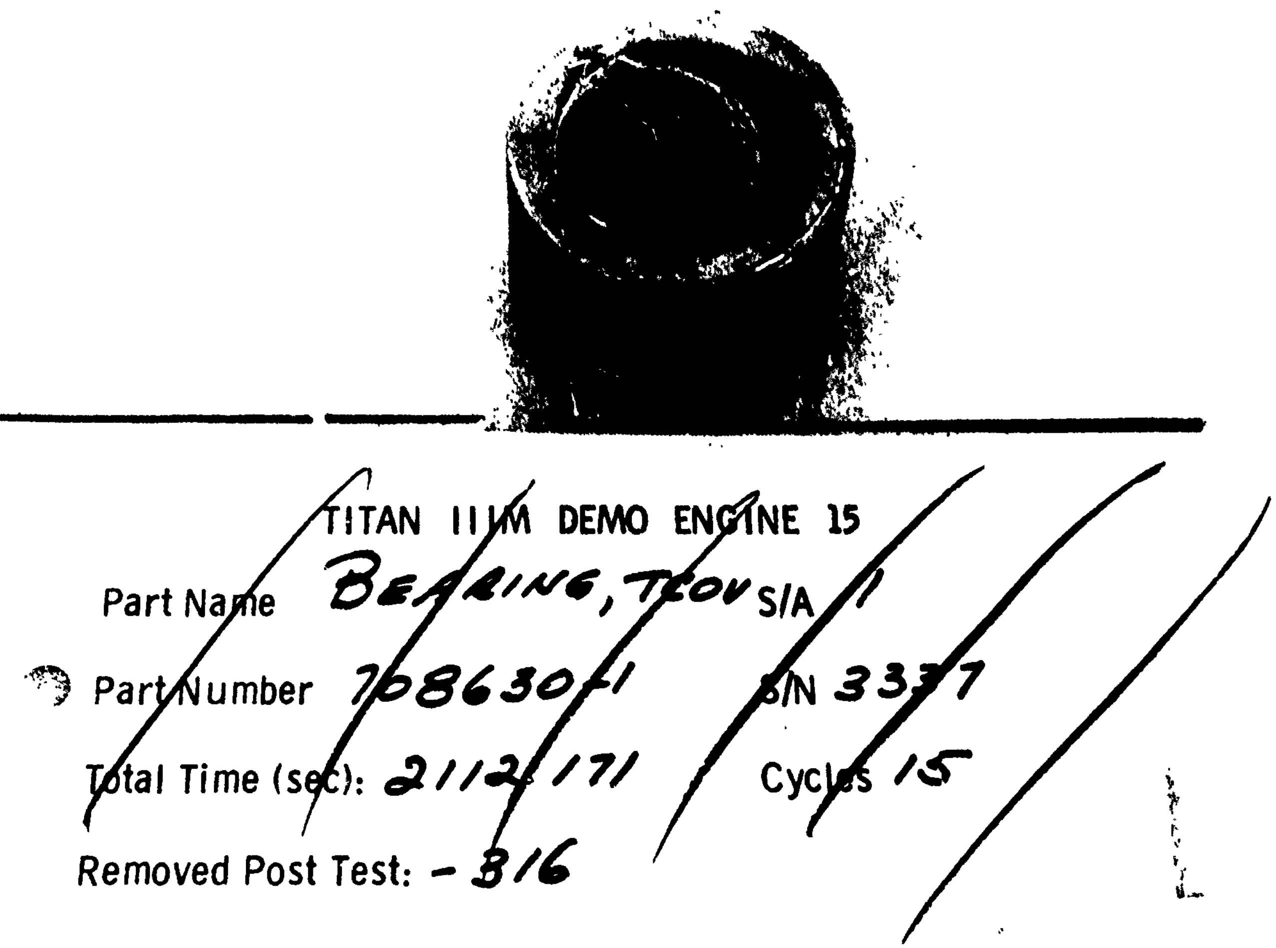


Figure 83 -- Bearing Liner -- Oxidizer Thrust Chamber Valve

6, Discussion of Discrepancies (cont.)

6.5 GAS GENERATOR ASSEMBLY

6.5.1 Gas Generator Oxidizer Check Valve

Postfire leak checks following Test No. -315 showed that the oxidizer check valve of Subassembly 2, engine S/N 15, leaked in the reverse-flow direction at approximately 12,000 cc/min.

A review of shutdown transient data from Test No. -315 suggests that the valve did not close or seat properly. The turbine inlet temperature rose after shutdown to 1830°F and remained above 1700°F for approximately 8.5 sec indicating that the generator combustion continued at a high mixture ratio.

The check valve was removed, disassembled and thoroughly examined. There was no evidence observed in the valve or adjoining components that would indicate any cause for the leakage.

The check valve was reinstalled on the engine and operated successfully on the next test.

7. Engine Reliability Assessment

7. ENGINE RELIABILITY ASSESSMENT

The Time-Cycle Summaries presented in Tables 44 and 45 show the total time and cycles accumulated on each serialized engine component, its subassembly designation, and when it was removed from the engine.

The Time-Cycle logs (Appendix D) show each individual test conducted on engine Demo 14 and Demo 15, date of test, duration of test, serialized components installed for each test, and remarks regarding replacement and prior usage, if any, of the components.

The following remarks apply to engine S/N 14:

1. On Test No. -212 fuel suction spools P/N 1122210-9 and P/N 1122214-9 were installed in compliance with POGO test requirements. On Test No. 3051-D07-1A-215 fuel suction spool P/N 41600-1 was installed on Subassembly 1.

2. On Test No. -206 combustion chambers S/N 017 and S/N 019 were removed and installed on the opposite subassembly.

The following remarks apply to engine S/N 15:

1. On Test No. -309, Subassembly 1 failed to start because of a failure of the pressure sequence valve (PSV) override solenoid. Consequently, the TCA did not experience hot fire. For time and cycle recording purposes, the TCA components will have 2.569 seconds and one cycle less than the engine and remaining components.

2. On Tests Nos. -309, -310, -312, -314, and -316 fuel suction spools P/N 1122210-9 and P/N 1122214-9 were installed in compliance with POGO test requirements.

7, Engine Reliability Assessment (cont.)

3. Fuel suction spool, P/N 1122210-9, S/N 721, was also fired on Test No. -212, for 201.006 seconds, while installed on engine S/N 14.

Time/cycle data from the lemonstration Program have been reviewed to determine if any changes or additions are required to the existing limits in the System Effectiveness Implementation Plan. The review indicated the following:

1. Elbow, vaned - Fuel valve outlet. The existing limit of 1210 seconds can be increased to 1680 seconds. Four parts were used on the Demonstration Program without change.

2. Second Stage Nozzle. A new design is currently being developed. Upon completion of CCN 74 a determination of required limit, if any, will be made.

Table 44 -- Time and Cycle Summary, Engine S/N 14

Total Engine Time: 1844.968 sec/15 cycles

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
Frame Assembly	1129050-19	605	1	1844.968	15	-215
Fuel Discharge Line	256866-19	054	1	1844.968	15	-215
		131	2	1844.968	15	-215
Oxidizer Discharge Line	265382-19	476	1	1844.968	15	-215
		478	2	1844.968	15	-215
Fuel Suction Line	294252	695	1	1443.504	13	(1)
	255639-19	647	2	1643.962	14	(1)
	1122210-9	721	1	201.006	1	(1)
	1122214-9	722	2	201.006	1	(1)
	41600-1	037	1	200.458	1	(1)
Oxidizer Suction Line	294251	624	1	1844.968	15	-215
		625	2	1644.510	14	-214
		628	2	200.458	1	-215
Fluid Heater	261285-39	378	1	1844.968	15	-215
		376	2	1844.968	15	-215
Hot Gas Cooler	284899-19	753	2	536.505	4	-204
	1154573-1	755	2	1308.463	11	-215
Gas Generator Assembly	709987-19	492	1	1844.968	15	-215
		493	2	1844.968	15	-215
Gas Generator Chamber	250375-79	492	1	1844.968	15	-215
		493	2	1844.968	15	-215
GGFCKV	705574-39	504	1	1644.510	14	-214
		506	2	1844.968	15	-215
	X8230-16MA	X-1	1	200.458	1	-215
GGOCKV	702642-59	871	1	1844.968	15	-215
		872	2	1844.968	15	-215
FBTL	259387	540	1	1844.968	15	-215
		543	2	1844.968	15	-215

Table 44 -- Time and Cycle Summary, Engine S/N 14 (cont.)
Total Engine Time: 1844.968 sec/15 cycles

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
OBTL	1181888-1	1604	1	1844.968	15	-215
		1605	2	1844.968	15	-215
TCA	1131273-9	475	1	1844.968	15	-215
		476	2	1844.968	15	-215
TCOV	130063-19	606	1	1844.968	15	-215
		604	2	1844.968	15	-215
First-Stage Rotor	1154950-1	001	1	1649.619	11	-310
		759	2	1458.769	11	-310
	1154950-2	783	1	666.111	6	-316
		788	2	666.111	6	-316
Second-Stage Rotor	1130974-3	896	1	2315.730	17	-316
		807	2	2124.880	17	-316
Turbine Manifold	1122654-59	047	1	2412.570	18	-316
		048	2	2317.170	17	-316
Gearbox Assembly	1131351-59	388	1	2612.570	19	-316
		390	2	2517.170	18	-316
Lube Oil Cooler	1130728-3	164	1	2114.740	16	-316
		165	2	2114.740	16	-316
Turbine Rotor Bolt	1130976-29	051	1	2412.570	18	-316
		055	2	2317.170	17	-316

Table 44--Time and Cycle Summary

Component	Part Number	SN	SA	Total Accum., Time	Total Accum., Cycles	Removed Post 3051-D07-1A
TCFV	1130064-9	674	1	1844.968	15	-215
		676	2	1844.968	15	-215
PSV	1131736-9	643	1	1844.968	15	-215
		644	2	1844.968	15	-215
Fuel Elbow (U/S)	255662-29	730	1	1844.968	15	-215
		731	2	1844.968	15	-215
Fuel Elbow (D/S)	285992-9	236	1	1844.968	15	-215
		237	2	1844.968	15	-215
Oxidizer Elbow	131576-1	007	1	1844.968	15	-215
		003	2	1844.968	15	-215
Gimbal Assembly	1129352-39	003	1	1844.968	15	-215
		002	2	1844.968	15	-215
Combustion Chamber	1130174-79	017	2	337.214	3	-206 (2)
		017	1	1086.687	9	-215
		019	1	758.281	6	-206 (2)
		019	2	221.814	2	-208
		020	2	421.067	3	-203
	1133311-19	092	2	864.873	7	-215
Dome Assembly	1129910-17	523	1	1844.968	15	-215
		522	2	1844.968	15	-215
Injector Assembly	1130409-129	697	1	1966.068	17	-215
		696	2	1966.068	17	-215
TCPS	706472-19	1417	1	1844.968	15	-215
		1418	1	1844.968	15	-215
		1415	2	1844.968	15	-215
		1415	2	1844.968	15	-215
TPA	1131352-69	008	1	2044.968	16	-215
		010	2	736.585	5	-204
		0C6	2	2817.823	18	-215
Oxidizer Pump Housing	286706-9	825	1	2044.968	16	-215
		799	2	736.585	5	-204
	282197	656	2	2817.823	18	-215

Table 44--Time and Cycle Summary (cont.)

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
Fuel Pump Housing	286707-9	915	1	2044.968	16	-215
		924	2	736.585	5	-204
	282185	664	2	2817.823	18	-215
Oxid. Pump Impeller	246626-5	2894	1	2044.968	16	-215
		856	2	736.585	5	-204
		2548	2	2817.823	18	-215
Fuel Pump Impeller	246627-5	2898	1	2044.968	16	-215
		2860	2	736.585	5	-204
		2859	2	2817.823	18	-215
Oxid. Pump Seal	291377-19	1349	1	2044.968	16	-215
		1346	2	736.585	5	-204
		1320	2	2817.823	18	-215
Fuel Pump Seal	291378-9	1354	1	2044.968	16	-215
		1355	2	736.585	5	-204
		1340	2	2817.823	18	-215
Turbine GB Seal	1132400-9	4741	1	1380.095	10	-208
		4744	2	936.585	6	-204
		4742	2	2152.950	12	-208
		4793	1	864.873	7	-215
		4874	2	864.373	7	-215
Second Stage Nozzle	260825-11	658	1	736.505	5	-204
		660	2	736.585	5	-204
		665	1	664.480	6	-210
		596	2	866.670	7	-210
		685	1	643.983	5	-215
		745	2	643.983	5	-215
First Stage Rotor	1130119-1	607	2	219.737	2	-201
	1130983-1	164	1	219.657	2	-201
		622	1	601.420	3	-203
		624	2	200.825	1	-202
		638	2	516.143	3	-204
		637	1	315.428	2	-204
	1154300-5	006	1	2521.373	17	-215
	1154950-1	004	2	1510.653	12	-215

Table 44--Time and Cycle Summary (cont.)

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
Second Stage Rotor	1130120-3	799	1	219.657	2	-201
		797	2	219.737	2	-201
	1130974-1	002	1	601.420	3	-203
		003	2	200.825	1	-202
		005	1	315.428	2	-204
		008	2	516.143	3	-204
		895	1	1308.463	11	-215
		810	2	1308.463	11	-215
Turbine Manifold	1122654-59	045	1	2044.968	16	-215
		041	2	736.585	5	-204
		046	2	2817.823	18	-215
Gearbox Assembly	1131351-59	387	1	2244.968	17	-215
		389	2	936.585	6	-204
		155	2	3017.823	19	-215
Turbine Rotor Bolt	1130976-29	055	1	219.657	2	-201
		060	2	219.737	2	-201
		056	1	1825.311	14	-215
		061	2	516.848	3	-204
		053	2	1308.463	11	-215
Lube Oil Cooler	1130728-3	012	1	736.505	5	-204
		013	2	621.147	4	-203
		006	2	115.438	1	-204
		116	1	1308.463	11	-215
		171	2	1308.463	11	-215
Ablative Skirt	1129770-19	025	1	316.363	2	-206
		037	2	316.363	2	-206
	1133735-3	003	1	201.013	1	-214
		005	2	201.013	1	-214
	1154627-9	032	1	200.458	1	-215
		033	2	200.458	1	-215

Table 45--Time and Cycle Summary, Engine S/N 15

Total Engine Time: 2114.740 sec/16 cycles

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
Frame Assembly	1129050-19	606	1	2114.740	16	-316
Fuel Discharge Line	1133576-19	539	1	2114.740	16	-316
		542	2	2114.740	16	-316
Oxid. Discharge Line	1133568-19	554	1	2114.740	16	-316
		555	2	2114.740	16	-316
Fuel Suction Line	294252	696	1	1308.979	11	(2)
	255639-19	648	2	1308.979	11	(2)
	1122210-9	721	1	1006.767	6	(2),(3)
	1122214-9	704	2	805.761	5	(2)
Oxid. Suction Line	294251	623	1	2114.740	16	-316
		626	2	2114.740	16	-316
Fluid Heater	261285-39	190	1	2114.740	16	-316
		375	2	2114.740	16	-316
Hot Gas Cooler	1154573	754	2	2114.740	16	-316
Gas Generator Assy	709987-19	480	1	2114.740	16	-316
		491	2	2114.740	16	-316
Gas Generator Chamber	250375-79	480	1	2114.740	16	-316
		491	2	2114.740	16	-316
GGFCKV	705574-39	505	1	2114.740	16	-316
		507	2	2114.740	16	-316
GGOCKV	702642-59	873	1	2114.740	16	-316
		870	2	2114.740	16	-316
FBTL	259387	541	1	2114.740	16	-316
		542	2	622.861	4	-304
		536	2	1491.879	12	-316
OBTL	1131888-1	1608	1	2114.740	16	-316
		1609	2	2114.740	16	-316

Table 45—Time and Cycle Summary, Engine S/N 15 (cont.)

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
CA	1131273-9	477	1	2112.171	15	-316
		478	2	2114.740	16	-316
TCOV	1130063-19	605	1	2112.171	15	-316
		607	2	2114.740	16	-316
TCFV	1130064-9	677	1	2112.171	15	-316
		675	2	2114.740	16	-316
PSV	1131736-9	640	1	1245.699	8	-309
		642	2	2114.740	16	-316
		641	1	866.472	7	-316
Fuel Elbow (U/S)	255662-29	728	1	2112.171	15	-316
		729	2	2114.740	16	-316
Fuel Elbow (D/S)	1131273-7	273	1	2112.171	15	-316
		478	2	2114.740	16	-316
Oxidizer Elbow	1131576-1	005	1	2112.171	15	-316
		006	2	2114.740	16	-316
Gimbal Assembly	1129532-39	001	1	2112.171	15	-316
		004	2	2114.740	16	-316
Combustion Chamber	1133311-19	021	1	2112.171	15	-316
		022	2	2114.740	16	-316
Dome Assembly	1155273-1	004	1	2112.171	15	-316
		002	2	2114.740	16	-316
Injector Assembly	1130409-129	699	1	2112.171	15	-316
		698	2	2114.740	16	-316
TCPS	706472-19	1410	1	2112.171	15	-316
		1411	1	2112.171	15	-316
		1413	2	2114.740	16	-316
		1414	2	2114.740	16	-316

Table 45—Time and Cycle Summary, Engine S/N 15 (cont.)

Component	Part Number	SN	SA	Total Accum. Time	Total Accum. Cycles	Removed Post 3051-D07-1A
Ablative Skirt	1154627-9	035	1	200.645	1	-305
	1129770-19	038	2	200.645	1	-305
	1121077	014	1	200.470	1	-307
	1129770-19	021	2	200.470	1	-307
	1155706-1	039	1	200.809	1	-316
	1155706-1	040	2	200.809	1	-316
TPA	1131352-139	009	1	2412.570	18	-316
	1131352-139	011	2	2317.170	17	-316
Oxid. Pump Housing	286706-9	826	1	2412.570	18	-316
		810	2	2317.170	17	-316
Fuel Pump Housing	286707-9	910	1	2412.570	18	-316
		923	2	2317.170	17	-316
Oxid. Pump Impeller	246626-5	2893	1	2412.570	18	-316
		2892	2	2317.170	17	-316
Fuel Pump Impeller	246627-5	2895	1	2412.570	18	-316
		2896	2	2317.170	17	-316
Oxidizer Pump Seal	291377-19	1350	1	1746.459	12	-310
		1348	2	1651.059	11	-310
		1364	1	666.111	6	-316
		1363	2	666.111	6	-316
Fuel Pump Seal	291378-19	1353	1	2412.570	18	-316
		1351	2	2317.170	17	-316
Turbine GB Seal	1132400-9	4873	1	2114.740	16	-316
		4869	2	2114.740	16	-316
Second-Stage Nozzle	260825-11	662	1	920.691	6	-304
		333	2	825.291	5	-304
		659	1	825.768	6	-310
		666	2	825.768	6	-310
		743	1	666.111	6	-316
		746	2	666.111	6	-316

APPENDIX A

Demonstration Test Requirements
SSD-CR-65-8180-140, Revision 2
System Test Implementation Plan
Paragraph 1.21

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The following paragraphs are direct quotations from the System Test Implementation Plan, SSD-CR-65-8180-140, Revision 2. The section quoted covers the demonstration testing of the Stage I Titan IIIM engines and was the governing document under which the Demonstration Test Program was conducted.

1.21 ROCKET ENGINE ASSEMBLY STAGE I (DEMO)

1.21.1 Following the successful completion of the Stage I development testing, engine assembly sea-level testing will be performed to demonstrate capability and compatibility of the improved components and to establish the adequacy of the engine system during gimballing and simulate flight flow conditions. This testing will be accomplished with prototype hardware to confirm that the components selected as prototype meet all program objectives. Formal qualification procedures will not be performed during this test series. Achievement of the performance and operational requirements during these tests, including sea-level start capability, will qualify the engine for the Titan IIIM application.

1.21.2 Space System Division/AGC Interface Policy

1.21.2.1 Notification

The plan of engine design verification testing will be as presented in Paragraph 1.21.3. Changes to these plans will be coordinated with SSD, in

III, Design Verification Test Plan (cont.)

advance of the effectivity of the change. Scheduled firing dates will be announced as far in advance of the tests as is practicable, with a minimum of 2-1/2 days ahead of the first test in the program. Appropriate AF/Aerospace and AGC representatives will be provided notification of prospective firings, but may waive their intention to witness tests. No delay in a scheduled test will be made to await the arrival of a representative, or the receipt of a written waiver. The amount of advance notice required by the various representatives may be established, in writing, by the cognizant organization prior to the commencement of the engine demonstration test series.

1.21.2.2 Demonstration Procedures

a. This series of tests will be conducted in accordance with applicable Aerojet-General specifications and other documents which will have received prior approval by SSD/AFPRO. Documents which authorize modifications to those above, will require the approval of SSD designated representatives prior to their implementation.

b. Representatives of SSD and Aerospace will be present, as they may consider necessary, to witness all tests, inspections, formal postfire evaluations, and discuss hardware changes.

c. Component part changes, other than those specified in approved documents, identifying time cycle sensitive equipment, may require penalty tests at the discretion of SSD. To avoid program delays, SSD-AFPRO may authorize minor technical changes. AGC will be responsible, however, for submitting the necessary paperwork, for such approval.

III, Design Verification Test Plan (cont.)

d. Paperwork related to the Design Verification Test Series (Demonstration) will be identified with "DEMO" in letters of 3/4 in. minimum height. This will include documents pertaining to this test series only, such as special test requests, inspection reports, discrepancy or failure analyses, etc., and will not include specifications or formal reports.

e. In the event the disposition of a discrepancy by Engineering requires approval of SSD-AFPRO, then AGC Test Operations Quality Control, Engineering, or Manufacturing Coordination Departments, as applicable, will present the inspection report (IR), to the local AFQC Representation for approval. The AGC-QC department handling the IR will contact the plant representatives of SSD/Aerospace, with Engineering personnel as necessary, to obtain approval signatures for the disposition.

1.21.3 Design Verification (Demonstration) Hardware Adjustment, Removal, Replacement, Repair, Rework, and Evaluation Procedures

The following paragraphs provide the basic requirements for the adjustment, removal, replacement, repair, rework, reinstallation and investigation of demonstration (DEMO) hardware. All such operations will be conducted in accordance with appropriate documents and requisite approvals.

a. By definition, the demonstration hardware, discussed below, consists of those new, or redesigned, components of the Titan IIIM engine system listed, as/or related to, those line items specified in the Titan IIIM System Program Statement of Work, Section 6.0 (AVE). Other engine components have been previously qualified on the Titan II, Titan III, and Gemini Programs; however, in the event of a failure of a nondemonstration component, investigation will be performed to ascertain the cause and determine corrective action, if necessary.

III, Design Verification Test Plan (cont.)

b. All parts, including expendable hardware, with the exception of solid start cartridges, which are damaged, or replaced for any reason, after an engine has been accepted for engine demonstration testing, or during the test series, will be documented in the engine logbook and retained in a designated storage area for display subsequent to the completion of testing.

1.21.3.1 Hardware Repair

1.21.3.1.1 With approval of SSD-AFPRO, minor hardware repair or rework required during the demonstration engine test series will be allowed and will not invalidate prior testing. Minor repair is defined as "repair defined in process specifications or approved production procedures which shall restore a component to a fireable condition or blueprint requirements." Examples of allowable rework or repair would be replacement of combustion chamber wire wrap or epoxy, repair of combustion chamber hot gas leakage, repair of coolant tube leakage, injector baffle repair, static seal leakage, and TPA dynamic seal leakage. The foregoing component repair procedures exist in current production planning and would require some modification to make the procedure applicable to the Titan IIIM hardware. All items for rework or repair shall require SSD-AFPRO approval.

1.21.3.1.2 Rework of hardware is defined as the correct reassembly of a component to blueprint specification. All rework will be completely documented, and will require SSD approval prior to reassembly of the part.

1.21.3.1.3 Repair of hardware is considered to be an operation which unalterably modifies a part resulting in a permanent departure from the specification or blueprint configuration. No repair work will be initiated without SSD-AFPRO

III, Design Verification Test Plan (cont.)

prior approval. Prior to initiation of any irreversible work, detailed record will be made of the "as is" condition of the part by means of photography, dimensional inspection, or other appropriate method which does not affect the condition of the part. Copies of the record(s) will be attached to the documentation of the repair procedure.

1.21.3.2 Hardware Replacement

1.21.3.2.1 With approval of SSD-AFPRO, replacement of engine components will be allowed after peripheral engine tests without invalidating prior tests providing the component is not repairable using established repair procedures. Component replacement after peripheral tests will require SSD-AFPRO approval. If a component fails during a peripheral test that peripheral test will be repeated. Replacement of those components listed below will require an additional 20 sec adjustment and 200 sec duration nominal test prior to continuing the test series.

TPA
TPA Impellers
TPA Pump Housing
Injector (TCA)
Combustion Chamber
Gearbox, bearings, gears

III, Design Verification Test Plan (cont.)

1.21.3.2.2 Component replacement without invalidating prior tests will be allowed starting with test number 8 of Table III-3. Hardware replacement of components not listed will be accomplished with SSD-AFPRO approval and will not require additional testing. AGC shall not be liable for hardware replacement or retests due to engine hardware damage or invalid test results caused by failure of the GFP TCA thermal insulation.

1.21.3.2.3 Hardware replacement is the substitution of one part by another of the same part number. The installation will be accomplished by mechanical means, not by welding.

1.21.3.2.4 Expendable hardware includes start cartridge components, burst diaphragms, hot gas system fasteners, seals, and gaskets and may be replaced in accordance with standard test operating procedures. SSD approval or notification will not be required for replacement of expendable hardware; however, AGC-QC will maintain records of such changes, and retain the used hardware, suitably labeled, in a designated storage area for availability during post-series engine display.

1.21.3.3 Hardware Removal and Reinstallation (R&R)

Hardware removal and reinstallation (R&R) is defined as a process pertaining to hardware, which must be removed to permit access to or removal of another component. SSD will be notified, however, prior to the removal and replacement of any hardware and AGC must obtain SSD approval prior to the next test. Special processing or nonstandard cleaning of removed hardware will require prior approval by SSD. The procedure will be subject to AGC-QC and Air Force surveillance, and the standard procedural forms will be signed off by AGC-QC.

III, Design Verification Test Plan (cont.)

1.21.3.4 Hardware Evaluation is defined as a process, or processes, wherein hardware is subjected to inspection, test, and/or destructive analysis to determine the cause of a failure.

1.21.3.4.1 Any nonexpendable hardware which is considered to be the cause of a primary failure will be processed in accordance with the following procedures.

a. All investigations and analyses will be conducted in accordance with the preliminary disposition on an inspection report. The results of the investigation should be submitted, with the inspection report, for approval of the final disposition.

b. Prior to the performance of any portion of the investigation which is not in accordance with approved drawings or specifications, or which would result in an irreversible process of destructive testing, approval will be obtained from SSD/AFPRO.

c. Photographs, dimensional inspection, and/or other suitably definitive records of the initial condition of the hardware item will be made before the start of an investigative procedure which would irrevocably modify the part. Copies of records will be made a part of the inspection report and disposition package along with the results of the investigation.

d. All hardware, or available remains of same, which has undergone such investigation, will be stored in a designated area for availability during post demonstration engine display.

III, Design Verification Test Plan (cont.)

1.21.4 Test Plan

1.21.4.1 General

The test program will involve two each Stage I engines assembled from new prototype hardware to demonstrate performance repeatability and operation at nominal and peripheral flight conditions. The nominal performance phase of the test series will be conducted to determine mixture ratio repeatability, thrust growth characteristics, autogenous system performance, thrust capability, and specific impulse. The peripheral tests will determine engine operating capability at worst flight conditions for the ablative skirts and combustion chamber as well as engine operation at flight minimum inlet propellant pressures. The test series description and general test configuration are described in Table III-3. The test series will be identical for both engine systems. Solid start cartridges (SSC) will be utilized to start each engine on all full-duration tests. The SSCs will be provided with nozzle sizes calculated to provide ballistic weight flow within the approved specification range. All tests, with ablative skirts installed, will be configured to demonstrate gimballing capability, and will include the special instrumentation required to monitor the side-forces occurring during the tests. Pre- and posttest propellant samples will be taken.

1.21.4.2 Engine Calibration Tests

Each DEMO engine will require five short-duration tests to determine and/or verify the correct flow control devices required to achieve engine performance within the specification band. These tests will be started with pressurized nitrogen gas. Ablative skirts and gimbal systems will not be incorporated. Additional engine calibration may be required during the DEMO test series and the required flow control device changes shall be made without penalty testing.

III, Design Verification Test Plan (cont.)

1.21.4.3 Ablative Skirt Engine Demonstration Tests

The ablative skirts will be tested as indicated in Table III-3.

These tests will be fired for 200 sec minimum duration, with gimballing of the TCAs at $\pm 6°$, 0.5 cps with sinusoidal input, to be performed for a minimum of 10 sec in pitch plane and 10 sec in the yaw plane. Gimballing in both planes will occur during the periods of FS_1 + 5 sec to FS_1 + 30 sec and FS_1 + 165 sec to FS_1 + 190 sec to meet the 10 sec minimum test requirement. The gimbal actuators shall be instrumented to monitor side loads.

1.21.4.4 Tests Without Ablative Skirts

Thirteen tests on engine SN RD14 and engine SN RD15 will be conducted with gimbal actuator dummy struts, without ablative skirts. The inlet conditions are defined in Table III-3.

The 200 sec duration tests will be initiated by solid start cartridges within the specification ballistic weight flow band to demonstrate the effect on the engine start transient.

1.21.5 Performance Requirements

The engine shall meet the performance requirements of the end-item specification, CP-40224. Nominal and/or minimum engine performance requirements shall be achieved at standard inlet conditions, defined from nominal flight conditions, as listed below:

III, Design Verification Test Plan (cont.)

Specific impulse, minimum, vacuum, sec	297
Thrust, nominal, pounds	
vacuum	520,000
Mixture ratio, nominal	1.91
Engine hot fire duration, sec	200
Propellant temperature, °F	
Oxidizer	35-90
Fuel	35-90
Standard inlet conditions	
Fuel temperature (T_{fs}), °F	60
Fuel pressure (P_{fst}), psia	32
Oxidizer pressure (P_{ost}), psia	82
Oxidizer temperature (T_{os}), °F	60

1.21.6 Success Criteria

1.21.6.1 Performance on Tests 1 through 8, Table III-3, shall meet the requirements of Paragraph 3.1 of CP-40224.

1.21.6.2 The DEMO test program shall be considered successful upon completion of the tests specified in Table III-3.

1.21.7 Test Instrumentation

Instrumentation measurements for all the DEMO tests will include the standard parameters as shown in Table III-4 and will be used for performance evaluation, safety, and malfunction analysis. Alternative methods for obtaining parameter values as specified in AGC-TM-125 may be used when direct measurements are lost.

III, Design Verification Test Plan (cont.)

Flight instrumentation components will be tested in conjunction with the standard sea level equipment, until design verification requirements for same have been completed, in the manner described in Paragraph 4.0, Section I.

1.21.8 Special Data Reduction

Data which are utilized to establish performance values achieved and show compliance to the end-item specification limits will be reduced and subsequently summarized in a final test data package for each test.

1.21.9 Post-Demonstration Test Display

1.21.9.1 General

The final phase of the design verification program will be conducted approximately 30 days after the last engine test, to verify that the new or redesigned components of the engines, which have satisfactorily completed the series, have accomplished that objective with a minimum of physical change. Parts that were replaced during the series, in accordance with the rules outlined in Paragraph 1.21.3.2 will also be displayed for examination in conjunction with the dossier of each, which will describe the investigation and conclusions, if required.

New or redesigned parts will be dismantled to such an extent as will facilitate examination. Such discrepant conditions of any components which were on the engines at the completion of the series will be displayed with applicable documentation. The dismantled hardware will be plainly identified, in the display, to differentiate between components which were on the engines at the completion of the series, and others which were removed previously.

III, Design Verification Test Plan (cont.)

Displayed hardware will be subjected to normal postfire cleaning procedures and inspection only, without alteration of any kind, except for items which have undergone failure investigations and may have required certain alterations or special cleaning in the process.

Any deviations to the above will require disposition by cognizant engineering personnel with the approval of SSD.

1.21.9.2 Disassembly and Display Procedure

a. The engines will be disassembled, in an "as-is" condition, to the level necessary to permit visual examination of all new or redesigned parts.

NOTE: The "as-is" condition is specifically defined as the condition in which the engine was received in the display area. The engines will have been cleaned in accordance with the standard test operations procedures. No rust removal, deburring or refinishing of surfaces will be performed. Residual liquids may be drained and/or wiped from the components, provided that the "as-is" condition is not violated.

b. The display will be conducted in an area to which only persons with a "need to know" will be admitted.

c. The arrangement of the display will provide: (1) clear identification of parts, (2) neat presentation, (3) logical breakdown of components, (4) ample space for the display, (5) ease of access for examination of the parts.

III, Design Verification Test Plan (cont.)

d. All displayed parts will be identified by name, part, and serial number (if serialized), with appropriate documentation readily available, if required.

e. Small items, such as nuts, bolts, screws, washers, and small seals will be displayed in transparent plastic containers with proper identification and quantity provided.

f. Components which were not on an engine during its final test will be displayed in the same manner, as above, but in a clearly differentiated area. Complete documentation of these parts will be available in the display area.

1.21.9.3 Final Hardware Disposition

Subsequent to the formal display, the reusable components will be cleaned, refurbished, packaged, and stored for future use. Items which cannot be reused will be scrapped in accordance with applicable regulations.

1.21.10 Report Requirements

At the time of the engine postfire display, a preliminary report will be made available. This report will include: a summarized history of all the tests on each engine, a parts replacement history, parts repair history, and a run by run tabular comparison of the actual engine performance with the values stated in the applicable specification. This document will be essentially of the same format as a final report to be submitted approximately 30 days after the formal display.

TABLE III-4

INSTRUMENTATION PARAMETERS

Parameter	Symbol
Fuel flow	FM_F
Oxidizer flow	FM_o
Thrust chamber pressure	P_c
Barometric pressure	P_{amb}
Ambient temperature	T_{amb}
Fuel pump inlet temperature	T_{fs}
Oxidizer pump inlet temperature	T_{os}
Fuel pump suction pressure	P_{fs}
Oxidizer pump suction pressure	P_{os}
Turbine hot gas inlet static temperature	T_{Ti}
Turbine speed	N_T
Gas pressure, fuel pressurant orifice inlet	P_{fpOi}
Gas temperature, fuel pressurant orifice inlet	T_{fpOi}
Gas pressure, oxidizer pressurant orifice inlet	P_{opOi}
Gas temperature, oxidizer pressurant orifice inlet	T_{opOi}
Fireswitch trace	FS
*Gimbal pitch position trace	L_{GP}
*Gimbal yaw position trace	L_{GY}
Voltage, d-c, supplies	E_{dc}
**TCPS actuation, each subassembly	TCPS

*Gimbal test only.
**Stage I only.

Report 9180-941-DR-9, Appendix B

ENGINE TEST OPERATING PROCEDURE 9111-87*
DESIGN VERIFICATION TEST PROGRAM (DEMO)

Revised 29 May 1968

TABLE OF CONTENTS

APPENDICES

*Including SATRS 1 through 40.

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1.0 SCOPE

1.1 This document establishes the standard procedures for operating and handling LR87-AJ-11 engines during the Design Verification Test Program (Demo) and is intended for use only when made applicable by appropriate Test Requests, engineering drawings and/or specifications. In the event of conflict with the End Item Specification, drawings or other applicable documents establishing requirements, the Project Engineering shall determine governing criteria.

2.0 APPLICABLE DOCUMENTS

2.1 GOVERNMENT DOCUMENTS -- AS SPECIFIED IN CP-40224

2.2 AGC DOCUMENTS

Specifications

CP-40224	End Item Detail Specification, Engine, Rocket, Liquid Propellant LR87-AJ-11
AGC-44055	Specification, Propellants Used in LR87-AJ-5 and LR91-AJ-5 Rocket Engines

Publications

TM-125	Estimate of Instrumentation Accuracy for Performance Calculations
ADS-5217	Identification, Fluid Line and Conduit Application and Installation of
SSD-CR-65-8180-140 Revision 2	System Test Implementation Plan

Drawings

294856	Flow Diagram, LR87-AJ-9
1129200	Assembly, Rocket Engine, LR87-AJ-11 (AF 04(695)-941 Contract)

3.0 OPERATING PROCEDURES

3.1 ENGINE RECEIVING INSPECTION

3.1.1 Upon receipt of the engine or component hardware in the test area, a visual inspection shall be conducted by the Test Engineer and Quality Control Inspector to ensure that the engine or hardware is in acceptable condition. Visual inspection should include, but not be limited to, the following:

a. Obvious abnormalities or damage.
b. Unit received with all protective covers and closures installed.
c. All lines inspected for nicks, dents, and distortion.
d. All lines identified per ADS-5217.
e. Unit inspected for loose or missing hardware.
f. Loose or missing torque seal, and safety wire.
g. Flange fittings for misalignment and protruding seals.
h. Remove suction closures and inspect the turbopump assembly (TPA) for any foreign material.
i. Combustion chamber coolant tubes for dents.
j. Close-up photographs, 8-1/2 x 11 in., required following inspection of engine received. (Three copies each with caption)
k. Close-up photographs, 8-1/2 x 11 in., required of components following installation on the engine. (Three copies each with caption)

3.2 ENGINE OR COMPONENT INSTALLATION

3.2.1 After completion of the visual inspection of the engine or components, all necessary propellant, instrumentation, drain and purge lines shall be connected using torque values specified in the applicable blueprints and/or documents and the lubricants specified in Appendix A. Close up and overall view photographs 8-1/2 x 11 in. (three copies each with caption) of instrumentation,

3.5, Table of Required Operations -- Pre- and Postfire

Function	Refer. Para.	Prefire: Initial Test	Prefire: Repl./Remov	Prefire: Normal	Postfire: Conditional	Postfire: Normal
D. Servicing/Installation						
Venturi/Orifices	3.5.4.1		X			
Solid Cartridge	3.5.4.2			X		X
Burst Discs	3.5.4.3			X		
Ablative Skirt	3.5.4.4			X(2)		X(2)
Raco Seals-CC	3.5.4.5					X
Systems Drain	3.5.4.6			X		X
Autogenous Cleaning	3.5.4.7					X
Engine Cleaning	3.5.4.8					X
Lube Oil/Filter	3.5.4.9	X		X		X
E. Other						
Photography	3.5.5.1			X	X	

(1) Gimbal tests only.
(2) Ablative skirt tests only.

3.5.1 Inspections

3.5.1.1 Engine Assembly

Following all prefire operations a walk-around visual inspection shall be conducted to assure all hold-fire tags have been removed and/or accounted for and check lists have been completed.

As soon as practical after each test, a visual inspection shall be made of all engine hardware for damage, hot spots, leakage, or other abnormalities that could preclude further tests of the existing hardware. 8-1/2 x 11 in. photographs (three copies each with captions) of damaged or discrepant hardware shall be obtained, and damage reported to Project Engineering.

3.4, Engine Postfire Operations (cont.)

under checkout or (2) reinstallation is not insured by a check list or (3) the item is not reinstalled prior to leaving the job unattended or (4) a potentially unsafe condition has been created.

3.5 TABLE OF REQUIRED OPERATIONS -- PRE- AND POSTFIRE

		Prefire			Postfire	
Function	Refer. Para.	Initial Test	Repl./ Remov	Normal	Conditional	Normal
A. Inspections						
Engine	3.5.1.1			X		X
CC & Skirt Diameters	3.5.1.2	X	X			X
CC-Inj. Gap	3.5.1.3	X		X		X
Tripod-Disch. Lines	3.5.1.4	X	X		X	
Turbine-TPA	3.5.1.5				X	
Impeller/Hsg.-TPA	3.5.1.6				X	
Gimbal Insp.	3.5.1.7					X(1)
B. Functional/Checkouts						
Engine	3.5.2.1	X	X			
Gimbal	3.5.2.2			X(1)		
N_2 Start Calib.	3.5.2.3	X	X			
TPA Torque	3.5.2.4	X				X
Purge Calib.	3.5.2.5	X	X			
C. Leak Checks						
Propellant Systems	3.5.3.1	X	X			X
P_{c5}	3.5.3.2	X	X			X
Hot Gas (TPA/GGA)	3.5.3.3	X	X			X
Autogenous	3.5.3.4	X	X			X
Electrical Controls	3.5.3.5	X	X			X
CC	3.5.3.6	X	X			X
Propellant Supply	3.5.3.7	X	X			X
Seals-TPA	3.5.3.8	X	X			X

*If gimbal required

3.2, Engine or Component Installation (cont.)

purge lines, etc., are required. Overall view photographs, 8-1/2 x 11 in. shall be taken of the test facility (G-1, G-2, G-3), one from the ramp and another 180° from the ramp.

3.3 ENGINE PREFIRE OPERATIONS

Prior to each test, all of the applicable operations presented in the following Table of Required Operations shall be performed to prepare the engine for a test firing.

3.3.1 Hold-fire tags will be used during test preparation when an item is loosened or removed from the engine, component or facility if: (1) the item interferes with the system under test or (2) reinstallation is not insured by a check list or (3) the item is not reinstalled prior to leaving the job unattended or (4) a potentially unsafe condition has been created.

3.3.2 Tests shall not be performed until it has been verified that all hold-fire tags are rematched or accounted for. Tests shall not be performed until the Test Instrumentation Engineer has verified proper instrumentation for the scheduled test.

3.4 ENGINE POSTFIRE OPERATIONS

Following each test, all of the applicable operations presented in the following Table of Required Operations shall be performed.

3.4.1 Hold-fire tags will be used when an item is loosened or removed from the engine, component or facility if: (1) the item interferes with the system

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

3.5.1.2 Measurement of Thrust Chamber Throat and Exit Diameters

Diametric measurements shall be taken of the throats and exits, or throats and skirt exits. Throat diameters shall be recorded to the nearest 0.001 in. Exit diameters shall be recorded to the nearest 0.100 in.

A minimum of four measurements at equal angular intervals shall be made at each location.

Measurements shall be taken both prior to and after a test. Redundant measurements are not required except when chamber or skirt have been replaced.

3.5.1.3 Inspection of Combustion Chamber/Injector Flange and Seals

a. A visual inspection shall be made to determine if the Teflon seal protrudes from the flanges. No protrusion is acceptable.

b. The flange surface clearance (gap) shall be measured with a feeler gauge around the full circumference. The gap is not to exceed 0.020 in. at any point in the full circumference of CC/injector flanges. The feeler gauge must not be inserted over 0.040 in. into the flange gap. Record the gap measurements and locations of seven points at equal angular intervals.

c. The visual and gap inspections shall be performed prior to and after each test.

3.5, Table of Required Operations — Pre- and Postfire (cont.)

3.5.1.4 Discharge Line Bellows (Tripod) Inspections

a. The bellows assemblies of fuel and oxidizer discharge lines, PNs 256866-19 and 265382-19, respectively, shall be dimensionally inspected for overall lengths.

b. Each bellows shall be measured and recorded at 90° intervals (4 places). The average of the four dimensions must be as follows:

Oxidizer Discharge Bellows	2.10 in. minimum
Fuel Discharge Bellows	1.95 in. minimum

c. Inspection of the bellows shall be performed prior to the initial test, between tests and after any disconnection, removal or replacement of a discharge line.

3.5.1.5 Turbine Assembly Visual Inspection

If, during a test, any of the following conditions occur, the turbine assembly shall require disassembly and inspection of the components:

a. After any test during which TTi exceeds 1700°F during steady-state operation.

b. After any test in which a valid OST shutdown occurred.

c. TTi exceeding 2000°F during a start or shutdown transients.

d. TTi exceeding 1700°F for a period greater than 2 sec during start or shutdown transients.

3.5, Table of Required Operations — Pre- and Postfire (cont.)

3.5.1.6 Pump Housing and Impeller Inspection

a. If pump inlet conditions fall below the minimum net positive suction (NPSH) values as shown below, the pump shall be disassembled and inspected if either of the following conditions are reached:

(1) Cumulative start transient operation below the minimum NPSH values reaches 10 sec.

(2) Cumulative steady-state operation below the minimum NPSH values reaches 450 sec for the oxidizer pump or 200 sec for the fuel pump.

b. The minimum NPSH supplied to the engine shall be as follows:

	Oxidizer	Fuel
Start Transient, Min, ft	44	43
Steady State, Min, ft	72	58

3.5.1.7 Gimbal Inspection

a. After gimbal calibration and after each gimbal test, check gimbal race retainers for looseness or breakage. If gimbal race retainers are found loose or broken, Project Engineering must be notified and the gimbal must be repaired or replaced prior to any further gimballing.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

3.5.2 Functionals, Checkouts and Calibrations

3.5.2.1 Engine System Functional

a. Functional checks, consisting of simulating the sequence of events of the engine and test stand equipment including the sequence unit as they occur during engine tests shall be conducted (1) prior to the initial test of the engine, and (2) at discretion of Test Engineer.

b. After replacement of the TCA, TCVPSV, TCOV, TCFV, or TCPS, a component check will be conducted to verify satisfactory operation of the replaced components.

c. The functional checks shall verify the following operations:

(1) Normal start and shutdown
(2) TCPS operation
(3) OST shutdown

d. The time durations of the following functions shall be verified and documented from the above sequence/functional checks:

(1) Duration of MXGVTPA (as specified on Pre-Dec)
(2) Duration of TPAXGV (approximately same as MXGVTPA)
(3) LTCV(O) (0.70 to 1.0 sec)
(4) TCVPSV(OR) to initial LTCV(C) (0.03 to 0.06 sec)
(5) LTCV(C) (0.70 to 0.90 sec)
(6) FS_2 to TCOPV (2.0 to 2.1 sec, non-skirt tests only)

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

(7) FS_2 to TCOPV/TCFPV (0.0 to 0.07 sec, skirt tests only)

(8) OST lockout timer (2.0 to 2.03 sec, solid cartridge tests only)

e. The thrust chamber pressure switches (TCPS) shall be functional checked for compliance with the following settings:

Make	620 $\pm$ 20 psia
Break	5 to 50 psia below make

3.5.2.2 Gimbal Functional and Calibration

a. Prior to a gimbal test (gimbal operation required when instructed by TRS or Pre-Dec) the gimbal actuators shall be installed, functionally checked and calibrated. CAUTION: Do not exceed 26 rad/sec^2 during functional. The calibration shall be accomplished without an ablative skirt to prevent damage. A discharge line bellows inspection is required prior to the initial functional test.

3.5.2.3 N_2 Start System Calibration

a. The N_2 start system shall be calibrated in accordance with values specified by Project Engineering to ensure satisfactory operation during engine tests. A desired value of PXG-7 relative to PXG-0 will be required.

b. Notify Project Engineering any time the system configuration is changed for a new specified PXG-7 and/or PXG-0 value.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

c. Notify Project Engineering each time system components (start valve check valve) are replaced or serviced. Difference in valve opening and closing characteristics may necessitate adjustment of the start pressure and/or the MXGVTPA.

3.5.2.4 TPA Torque Check

a. A TPA torque check shall be made prior to the initial test and after each test to determine if the breakaway and running torques are within acceptable limits. Measured at the turbine, the maximum torque is 49 in.-lb initial breakaway and 39 in.-lb subsequent breakaway, and running through three revolutions.

b. As an alternate method, torque may also be measured at the accessory drive pad. Maximum torque for the alternate method is 25 ft/lb (300 in.-lb initial breakaway), 20 ft/lb (240 in.-lb) subsequent breakaway and running through three revolutions.

c. Under no conditions are the maximum initial breakaway torque values to be exceeded.

3.5.2.5 Nitrogen Purge Systems Calibration

a. The purge systems shall be calibrated to ensure operation at specified levels during test. The calibrations shall be performed prior to the initial test after any system modification or major component replacement.

b. The required pressures and locations for sea-level tests without ablative skirts are as follows:

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

Function	Calibration Pressure, psig	Where Measured
TCOP	35 ± 5	3-in. upstream of check valve on TCA TCOP lines
TCFP	35 ± 5	3-in. upstream of check valve on TCA TCFP lines
TPOCP	170 ± 10	3-in. upstream of check valve on TCA TPOCP lines
TCW**	60 to 200	Facility water system pressure

c. The required pressures and locations for sea-level tests with ablative skirts installed are as follows:

Function	Calibration Pressure, psig	Where Measured
TCOP	50 ± 5	At the injector TCOP inlet boss below the check valve
TCFP	50 ± 5	At the injector TCOP inlet boss below the check valve
TPOCP	170 ± 10	3-in. upstream of check valve on TPA TPOCP lines

3.5.3 Leak Checks

After the engine has been installed in the test stand and after each test, it will be necessary to conduct static leakage tests of propellant, hot gas, autogenous and electrical harness systems to verify integrity of engine and instrumentation connections.

Whenever any fitting or connection is disconnected and reconnected in the engine systems that fitting or connection will be leak checked. Leak checks may also be performed at the discretion of the Test Engineer.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

Prior to attaching any leak check hose or tooling to an engine fitting, assure the equipment is free of contaminants.

The systems to be leak checked are described in the following paragraphs. The allowable leakage rates for each system are specified in Appendix B.

3.5.3.1 Propellant Systems

This leak check includes the oxidizer and fuel systems upstream of the thrust chamber valves and oxidizer autogenous burst diaphragm.

3.5.3.2 Chamber Pressure Installation - Pc5

This leak check includes the pressure switches, tubing and instrumentation at both Pc5B and Pc5C locations.

No pressure decay is allowable in five minutes and no internal or external leakage allowed.

3.5.3.3 Hot-Gas System

This leak check includes the gas generator chamber, turbine assembly, exhaust duct (superheaters) and fuel autogenous installation (SA2).

Correction of minor leakage from the hot gas system may be postponed, if a test is impending, until after test completion. Such leakage shall be limited to a 0.5 psig pressure decay in five minutes.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

3.5.3.4 Autogenous Pressurization Systems

This leak check includes (1) the oxidizer superheaters and system installation between the burst diaphragm and engine/test stand interface, and (2) the fuel hot-gas cooler and installation between the turbine manifold and the burst diaphragm. An internal leak check of the hot-gas cooler shall be performed using the bubble detection method.

3.5.3.5 Electrical Controls Harness

This check shall include the conduits and junction boxes.

Correction of leakage may be postponed, if a test is impending, until after test completion provided a 5 to 10 psig N_2 purge is applied to the harness during test.

3.5.3.6 Combustion Chambers

Two leak checks are required to determine the suitability of the chambers for test (or retest).

External leakage of hot-gas and/or coolant tubes is detected by pressurizing the water-filled tubes and combustion zone.

Internal leakage is detected by examination of the water-filled coolant tubes under static head pressure.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

3.5.3.7 Propellant Supply (TCA and GGA)

This leak check includes the system downstream of the thrust chamber valves to the thrust chamber and gas generator and may be performed in conjunction with the combustion chamber external leak check (Para. 3.5.3.6).

3.5.3.8 Turbopump Seals

a. Leak checks shall be made of all TPA seals after each test to determine if the leakage rates, if any, are within the allowable limits as specified in Appendix B.

b. Seal Leak Check Procedure

To ensure that adequate oil is in the gearbox, perform the seal leak checks prior to draining or after a lube oil change.

(1) Rotate the accessory drive shaft for approximately 30 revolutions (equivalent to 200 revolutions on turbine shaft) within 2 hours of leak test. If seal leakage rate exceeds the maximum allowable rate as specified in Appendix B, rotate the shaft and recheck the seal leakage rate.

(2) The seal leakage is acceptable if, by rotating the shaft, a position can be found where the leakage rate does not exceed the maximum allowable rate as specified in Appendix B. Critical - Both the maximum and minimum seal leakage rates of each individual seal shall be recorded on the Test Remarks Sheet.

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

3.5.4 Servicing and Installation

3.5.4.1 Installation of Venturis and/or Orifices

Engine flow control devices may be changed prior to and after adjustment tests to optimize desired performance.

Specific sizes of flow control devices for a particular engine are determined by Project Engineering personnel. The sizes of the flow control devices, together with the desired operating conditions for the engine, will be supplied by Project Engineering on the Pretest Declaration of Intent for each test.

Metal identification tags must be safety wired to the line at the location of the flow control device indicating size and nomenclature. If no device is installed, the identification tag shall so indicate. Verify that the identification tag sizes agree with the sizes listed on the Pretest Declaration of Intent.

3.5.4.2 Solid Start Cartridge and Igniter

CAUTION: All operations involved in installation of solid start cartridges and igniters must be conducted in accordance with LRO Test Division Safety Procedures.

The solid start cartridges and igniters will be installed only after the majority of prefire operations have been completed.

3.5, Table of Required Operations — Pre- and Postfire (cont.)

As soon as practical after each test where solid start cartridges were utilized, the cartridges and igniters shall be removed from the engine in accordance with AGC LRO Test Division Safety Procedure 17.

3.5.4.3 Autogenous Burst Diaphragm Installation

Prior to each test the autogenous burst diaphragms shall be installed in the fuel and oxidizer pressurant lines.

Identification tags shall be attached following installation of the diaphragms and removed immediately prior to the test.

Verify that the inlet line (S-tube) to the oxidizer venturi/diaphragm housing assembly is completely drained prior to each test.

3.5.4.4 Ablative Skirt Installation

Install the ablative skirt with the white marker located directly under the combustion chamber manifold drain plug.

3.5.4.5 Raco Seal Replacement, Injector to Chamber Flange

Following the combustion chamber leak checks after each test, the chambers shall be carefully removed to permit inspection and replacement of the Raco seals. The condition of the seals, prior to and after removal, shall be documented. Serious or typical anomalies shall be photographed, 8-1/2 x 11 in. (Three copies each with captions.)

3.5, Table of Required Operations — Pre- and Postfire (cont.)

3.5.4.6 Systems Drain and Purge

Prior to each test, the engine systems shall be completely drained of all liquid (water and/or alcohol). Precautionary measures shall be taken to avert spillage onto skirts. Purges and/or propellant drain systems may be utilized for complete dissipation of all liquid from propellant passages. When all propellants have been drained from the systems, residual vapors shall be removed by means of a water aspiration system. The systems to be verified free of liquid should include, but not be limited to, the following:

a. The thrust chamber valve pressure sequence valve (TCVPSV) and thrust chamber fuel valve actuator (TCFV) shall be drained and purged following any valve actuation cycle.

b. Combustion chamber coolant tubes shall be completely drained of all liquid. The thrust chamber fuel purge shall be used to dissipate existing moisture in the coolant passages.

c. Oxidizer and fuel suction and discharge propellant lines shall be drained through a low point fitting and the residual moisture purged from the system.

3.5.4.7 Autogenous Component Cleaning

a. Gas Cooler Cleaning

The autogenous gas cooler and attached hot gas lines shall be cleaned after each test, or prior to any subsequent test, in order to retain satisfactory heat transfer capabilities of the system.

3.5, Table of Required Operations — Pre- and Postfire (cont.)

If cleaning cannot be accomplished within 12 hours, the requirement may be extended providing the cooler and inlet line are capped and filled with Del Chem solvent.

b. Superheater Cleaning

The autogenous superheater shall be cleaned within 24 hours after a test employing a solid start cartridge.

3.5.4.8 Engine Cleaning

The engine shall be completely decontaminated to prevent corrosion if propellants have been introduced into the engine, and it will not be refired within 28 days.

3.5.4.9 Lube Oil and Filter Cartridge (TPA)

a. Prior to each test the gearbox reservoirs shall be refilled with 2 gallons of lubricating oil conforming to MIL-L-7808D-1. During the oil fill, the oil shall be passed through a 55 micron absolute filter. The oil batch number shall be recorded on the Test Remarks Sheet.

b. After each test or at any time contamination of lubricating oil is suspected, the following operation will be conducted:

(1) The lubricating oil shall be drained from the TPA and chemically analyzed for the following: N_2O_4, AeroZINE 50 and H_2O. N_2O_4 shall not exceed 0.01% by weight; AeroZINE 50 shall not exceed 0.10% by weight;

3.5, Table of Required Operations -- Pre- and Postfire (cont.)

H_2O content shall not exceed 0.146% by volume as determined by Method 5001 of AGC-STD-3003. If the total drainage is less than 10 pints, Project Engineering, Department 9111, shall be notified.

(2) The lube oil filter cartridge shall be removed and visually inspected. If the test duration was greater than 50 sec, the cartridge shall be rinsed or replaced with a rinsed or cleaned cartridge. The lube oil filter cartridge shall be replaced if the pressure differential (ΔP10LHE-PgGB) exceeded 12 psi during test. (Do not install cartridge until gearbox flush has been completed.)

(3) The TPA gearbox shall be flushed with 2 to 3 gallons of fresh lube oil supplied to the Pld port at 20 to 35 psig (MIL-L-7808D-1) within 36 hours after a test.

3.5.5 <u>Other</u>

3.5.5.1 Photographic Coverage

Documentary motion pictures of each test shall be taken. All movies shall be in color. Two cameras shall be located on opposite sides of the engine to view the engine above the chamber exit flange. When ablative skirts are utilized, two additional cameras shall be located on opposite sides to view the skirt from the chamber attachment flange to the exit.

The roll (film) identification numbers for each test shall be documented on the Test Engineer Remarks sheets.

4.0 STANDARD INSTRUMENTATION

4.1 GENERAL

Standard test area instrumentation shall be used, as required, to achieve steady-state measurement accuracy of performance parameters in accordance with the latest revision of TM-125. Measurements not listed in TM-125 shall be within ±3%. All instrumentation equipment shall be within current calibration status, as evidenced by stickers or other records, in accordance with requirements of the Test Division reinspection program. Pressure transducer line lengths are not to be changed without concurrence of Project Engineering, Department 9111.

4.2 MEASURED PARAMETERS

The total instrumentation measurements and recording methods are presented in Appendix C. With exception to the selected parameters in the following table, changes and/or deletions may be made as necessary for special program requirements by coordination with Project Engineering, Department 9111.

The following table presents the prime (Category I) instrumentation required for performance evaluation, safety and malfunction analysis. Alternate methods for obtaining parameter values as specified in TM-125 may be used when direct measurements are lost.

CATEGORY I INSTRUMENTATION

Parameter	Symbol
Fuel flow	FM_F
Oxidizer flow	FM_O
Thrust chamber pressure	P_c
Barometric pressure	P_{amb}
Ambient temperature	T_{amb}
Fuel pump inlet temperature	F_{fs}
Oxidizer pump inlet temperature	T_{os}
Fuel pump suction pressure	P_{fs}
Fuel pump discharge pressure	P_{fd}
Oxidizer pump suction pressure	P_{os}
Oxidizer pump discharge pressure	P_{od}
Turbine hot gas inlet static temperature	T_{Ti}
Turbine speed	N_T
Gas pressure, fuel pressurant orifice inlet	P_{fpOi}
Gas temperature, fuel pressurant orifice inlet	T_{fpOi}
Gas pressure, oxidizer pressurant orifice inlet	P_{opOi}
Gas temperature, oxidizer pressurant orifice inlet	T_{opOi}
Fireswitch trace	FS
*Gimbal pitch position trace	L_{GP}
*Gimbal yaw position trace	L_{GY}
Voltage, dc, supplies	E_{dc}
TCPS actuation, each subassembly	TCPS
Bearing temperatures, TPA Nos. 1 through 11	T_{Bx}
Lube pressure, pump discharge (TPA)	P_{1d}
Gearbox pressure (TPA)	P_{gGB}
Differential pressure, lube system (ΔPld-PgGB)	$\Delta P1p$
Differential pressure, lube filter (ΔPLOLHE-PgGB)	$\Delta P1_F$

*Gimbal test only.

4, Standard Instrumentation (cont.)

4.3 TPA AND ACCELEROMETERS AND THERMOCOUPLES

4.3.1 The turbopump assemblies shall be instrumented with four accelerometers on each gearbox as specified in Appendix D.

4.3.2 Precalibrate magnetic tape recorder and perform a "tap" check prior to firing.

4.3.3 Assure that all bearing thermocouple probes are intact against bearing races.

4.3.4 A spring load bearing temperature probe, PN 1129464, shall be installed in the B-5 location.

4.3.5 A bearing temperature probe, PN 1130277-11, shall be installed in the B-6 locations.

4.4 RECORDING REQUIREMENTS

4.4.1 <u>ADC Recordings</u>

The minimum sampling rates shall be as follows:

10 samples per sec for normal channels
50 samples per sec for rapid sample (RS) channels
250 samples per sec for double rapid sample (DRS) channels
1 sample per sec FS_2 + 5 sec to FS_2 + 6 min (ablative skirt tests only)

4.4, Recording Requirements (cont.)

4.4.2 Strip Chart and Oscillograph Recordings

4.4.2.1 The minimum recording speed for the strip chart recorders shall be 1/4 in. per sec.

4.4.2.2 The recording speed for the oscillograph recorders shall be 16 in. per sec. Special speeds will be coordinated with test engineering.

4.4.2.3 The frequency response of the oscillographs and magnetic tape recorders shall be appropriate to the measurement system capabilities as required to permit engineering assessment of transient data.

4.5 ABLATIVE SKIRT INSTRUMENTATION

Ablative skirts equipped with thermocouples shall be instrumented and recorded.

Three general locations and identities are as follows:

TAS-6A	30° (CCW looking aft) from the white alignment stripe, 7.5 in. below the forward flange.
TAS-6C	30° (CCW looking aft) from the white alignment stripe, 10.0 in. above exit flange.
TAS-7	Incline with white alignment stripe, 22.0 in. below the forward flange.

5.0 SEQUENCE OF ENGINE OPERATIONS

5.1 Following completion of the prefire procedures, the engine shall be supplied with propellants and tested in accordance with the following sequence of operations.

5.2 PRIOR TO FS_1

Notify Project Engineering at least two hours prior to each test. A Project Engineering representative must be present for each test.

5.2.1 All ATP-TDO's, inspection discrepancies and IR dispositions shall be completed.

5.2.2 Start energy systems shall be verified (N_2 "K" bottles filled or start cartridge squib circuit armed).

5.2.3 Stand safety-valve, flowmeters, pressure transducers and propellant bleed visual indicators shall be checked during propellant drop to assure proper operation.

5.2.4 Suction pressures shall be set to maintain the NPSH (within limits specified on the Pretest Declaration of Intent) following engine start.

5.2.5 A hold-fire for the engine is to be initiated (1) if any quality discrepancies remain, (2) if engine or support component conditions warrant (Test Conductor's judgement), (3) at the discretion of Project Engineering, or (4) if any applicable special program limitations are not met.

5.2.6 Ensure that TC water nozzles are turned off or protected from inadvertent operation prior to testing an ablative skirt.

5.2.7 Test Engineer will verify that the delta temperature between T_{fs} and T_{os} is less than 10.0°F prior to FS_1.

5, Sequence of Engine Operations (cont.)

5.3 FIRE SWITCH ONE (FS_1)

The start signal to the N_2 start valve or solid start cartridge initiators is energized and the variable MXGVTPA runout timer is started. This timer shall be used to de-energize either the N_2 start valve or the solid state cartridge squib circuits. MXGVTPA timer settings for individual tests shall be specified on the Pretest Declaration of Intent

5.3.1 The TCPS switches "make" at 580 to 660 psia (chamber pressure).

5.3.2 The overspeed trip (OST) lockout timer expires at FS_1 + 2 seconds (solid start only).

5.3.3 The TCPS to be monitored foı function only, and will not provide engine shutdown.

5.3.4 At FS_2 - 10 seconds the thrust chamber water nozzles are activated "ON" (ONLY for normal shutdowns without ablative skirts).

5.4 FIRE SWITCH TWO (FS_2) WITHOUT ABLATIVE SKIRT

5.4.1 The FS_2 signal energizes the TCVPSV override, terminating the test and the engine completes the shutdown phase.

5.4.2 TCPS switches "break" at 540 to 660 psia.

5.4.3 At FS_2 + 2 seconds TCOP on.

5.4.4 At FS_2 + 120 seconds - TCOP off, TCWF on.

5.4.5 At FS_2 + 5 minutes - TCWF off, TCFP on.

5.4.6 At FS_2 + 9 minutes - TCFP off.

5, Sequence of Engine Operations (cont.)

5.5 FIRE SWTICH TWO (FS_2) WITH ABLATIVE SKIRT

5.5.1 The FS_2 signal energizes the TCVPSV override, terminating the test and the engine completes the shutdown phase.

5.5.2 The FS_2 signal energizes TCOPV and TCFPV.

5.5.3 TCPS switches "break" at 540 to 660 psia.

5.5.4 At FS_2 + 5 minutes, TCOP and TCFP off.

5.6 MALFUNCTION SHUTDOWNS

5.6.1 The test shall automatically be terminated by an overspeed trip signal any time the turbine speed (NT) exceeds the preset limit (except for the 2 seconds lockout employed on solid start tests).

5.7 SHUTDOWN PARAMETERS

5.7.1 The test shall be terminated manually if specified operating limits of test conditions are not met (Section 6).

5.8 EMERGENCY SHUTDOWN

5.8.1 Failure of the TCV's to close at FS_2 shall require an emergency shutdown (ESS). Initiation of an ESS signals the oxidizer safety valves to close, resulting in an oxidizer exhaustion shutdown.

6.0 ENGINE OPERATING CONDITIONS AND LIMITS

6.1 TEST DURATION

The test durations shall be 20 seconds for adjustment tests and 200 seconds for performance/peripheral evaluation tests or as specified in the Pretest Declaration of Intent.

6.2 PROPELLANT CONDITIONING

Propellants shall be conditioned for each test as specified in the Pretest Declaration of Intent.

6.3 ENGINE EXPOSURE

At the time of test, the engine shall not be statically exposed to an ambient temperature of less than +35°F or greater than +100°F without notification to Project Engineering.

6.4 GIMBAL TESTS

These tests will be fired for 200 seconds minimum duration with gimballing of the TCA's at $\pm 6°$, 0.5 cps with sinusoidal input, to be performed for a minimum of 10 seconds in the pitch plane and 10 seconds in the yaw plane. Gimballing in both planes will occur during the periods FS_1 + 5 sec to FS_1 + 30 sec and FS_1 + 165 sec to FS_1 + 190 sec to meet the 10 seconds minimum requirements. The gimbal actuators shall be instrumented to monitor side loads. Gimballing must be accomplished from the engine null only (+3 degrees outboard pitch).

6.5 KILL PARAMETERS

If the following parameter limits are exceeded during the test, the run shall be terminated.

6.5, Kill Parameters (cont.)

Turbine Inlet Temperature	TTi = 1750°F Max
Turbine Speed	OST = 27,500 ± 250 rpm Max
Lubricating Pump Net Pressures	LPLP = 10 psi Min
Gearbox Bearing Temperature	TB6 = 500°F Max
Gearbox Gas Pressure	PgGB = 50 psig Max

$NPSH_F$ = 43 feet (minimum allowable net positive suction head duration not to exceed 10 seconds)

$NPSH_O$ = 44 feet (minimum allowable net positive suction head duration not to exceed 10 seconds)

6.5 SPECIAL TORQUE CHECKS

When required and authorized, the following engine connnections or bolts must be retorqued to ensure the torque values are within specified limits. The maximum torque is not to be exceeded during this check.

	Min.	Max.
Gas Generator-Turbine Manifold Flange Bolts	260	320 in.-lb
Fuel Autogenous Gas Cooler-Inlet and Outlet Flange	55	60 in.-lb
Fuel Autogenous System-Turbine Manifold Flange	55	60 in.-lb
Autogenous Gas Cooler-Bypass Cover Bolts	25	30 in.-lb
Gas Generator Fuel Bootstrap Flex Lines Connections	1200	1400 in.-lb
Engine Frame (Corner) to Thrust Takeout Frame	600	750 in.-lb
Engine Frame (5th Member) to Center Post	200	250 ft-lb

8.0 SUCCESS CRITERA

8.1 SUCCESS

8.1.1 To be classified "success," performance evaluation tests must demonstrate the requirements specified in paragraph 3.1 of specification CP-40224.

8.1.2 To be classified "success," peripheral evaluation tests must demonstrate the requirements specified in Table III-3 of the System Test Implementation Plan (SSD-CR-65-8180-140, Rev 2).

8.2 FAILURE

8.2.1 If a test fails to meet the requirements for success, for reasons due solely to engine component malfunctions or incorrect system balance (except adjustment tests) the classification will be "failure."

8.3 EXCLUSION PRIOR (E-P)

8.3.1 All system checkout and balance adjustment tests shall be classified as exclusion prior (E-P) tests.

8.4 EXCLUSION AFTER (E-A)

8.4.1 If a test fails to meet the requirements for success, for reasons due solely to test stand support equipment malfunctioi and/or human error, then the test will be classified as exclusion after (E-A).

9.0 DATA SERVICES

9.1 GENERAL

9.1.1 The following data services shall be provided by LRO Test Division for all tests, as applicable to the type of test. Additional or special requirements will be authorized by Test Request Supplement, as required. Except as noted, all data and records shall be delivered to Project Engineering. Data filed in the Data Library shall be retained for at least twelve (12) months, after which it shall be sent to Project Engineering. No data shall be destroyed.

9.1.2 The Data Services requested herein do not include internal Test Division data requirements (Test Engineer, Data Analysis Group, Instrumentation Engineer, etc.).

9.2 DATA AND RECORDS DISTRIBUTION

9.2.1 Forward final data, millisadic and R-4 oscillograph to Project Engineering Department 9111 within four working hours after test.

9.2.2 Strip chart (Brown) recordings shall be forearded to Project Engineering, Department 9111, following test.

9.3 TEST RECORDS AND DATA

9.3.1 Test Remarks Sheets

Following each test deliver two copies of the Test Remarks Sheet to Project Engineering within seven calendar days. The original is to be filed in the Data Library.

9.3, Test Records and Data (cont.)

9.3.2 Oscillograph Records

All oscillograph records shall be identified at FS_1 and FS_2 by numbered light breaks. Copies of all instrumentation sheets to be provided to Projects within 48 hours by Test Engineering.

9.3.3 ADC Data Tabulations

Data, in engineering units, shall be tabu ated at normal frequency and two copies delivered to Project Engineering approximately four hours following each test. Normal frequency shall be:

FS_1 to FS_1 + 10 seconds	Every point
FS_1 + 10 to FS_2 - 5 seconds	One point every two seconds (duration test only)
FS_1 + 10 to FS_2 - 5 seconds	One point every second (adjustment test)
FS_2 - 5 to FS_2 + 5 seconds	Every point
FS_2 + 5 seconds to FS_2 + 6 minutes	One point every two seconds (ablative skirt tests only)

9.3.4 Balance Data

Two copies of the computer summarized card load data tabulation shall be delivered to Project Engineering within 10 hours following each test. The data shall be corrected to Standard Inlet Conditions. The required data summary periods are as follows:

a. FS_1 + 5 to FS_1 + 7 seconds - Equilibrium only.

b. FS_1 + 9 to FS_1 + 11 seconds - Equilibrium only.

9.3, Test Records and Data (cont.)

c. FS_1 + 19 to FS_1 + 21 seconds (or to FS_2 if sooner) - All balances and equilibriums.

d. FS_1 + 2 to FS_2 - All balances and equilibriums.

e. Midpoint to Midpont + 20 seconds - All balances and equilibriums, duration tests only.

f. Special summaries as required for test malfunctions, etc.

9.3.5 Final Plot Data

Within 36 hours following each test, 4 copies of each of the following 9 plots for each subassembly shall be delivered to Project Engineering.

Plot A. Transient Thrust Chamber Parameters vs Time

X-Axis: Time (sec) Split Scale - FS_1 to FS_1 + 1.75 sec and FS_2 - 0.25 sec to FS_2 + 1.50 sec.

Y-Axis: Pos-36A, PoJ3, Pfs-41A, PfJ-1, Tc5C, Pod, Pfd.

Plot B-1. Steady-State Gearbox Parameters vs Time

X-Axis: Time, 280 sec, major division equals 8 sec for duration. Best fit for short tests.

Y-Axis: TB-4, TB-5, TB-6, P_{1d} x 2.0 (psia), PgGB x 2.0 (psia), ΔP_{1d}-PgGB x 2 (psi), ΔPloLHE-PgGB x 100, 0 to 400 units, a major division equals 20 units.

Plot B-2. Steady-State Bearing Temperature vs Time

X-Axis: Time (sec) 0 to 280 seconds for duration test. Best fit for short test.

Y-Axis: TB1, TB2, TB3, TB7, TB8, TB9, TB10, TB11: 0 to 400°F, a major division equals 20°F.

9.3, Test Records and Data (cont.)

Plot C. Transient Gas Generator and Flow Parameters vs Time

X-Axis: Time (sec) Split Scale - FS_1 to FS_1 + 1.75 sec and FS_2 - 0.25 sec to FS_2 + 1.50 sec.

Y-Axis: PojGG, PfjGG, PcGG, PgSSC or (PXG-7), PoBTv, PfBTv, PTi, N_t.

Plot D. Special Thrust Chamber Parameters

X-Axis: Time (sec) Split Scale - FS_1 to FS_1 + 3, FS_2 - 0.5 to FS_2 + 2.5.

Y-Axis: PoJ3, PfJ1, Pci1, Pc5C, Tci1, ToJ-1, MRSA, LTCV.

Plot E. Steady-State Turbopump Parameters vs Time

X-Axis: Time, 0 to 280 sec, major division equals 8 sec for a duration test, best fit for short test.

Y-Axis: Pfd, Pfs-41 x 10, Pod, Pos-36 x 10, PTi, TTi-1, TTi-2, N_T x 0.05, Qo x 0.5, Qf x 0.5; 0 to 2000 unit, major division equals 100 units.

Plot F. Measured Thrust

X-Axis: Time (sec) FS_1 to FS_2

Y-Axis: Measured FSA, FB-N, FB-E, FB-W, FB-S, Pc5C, PTi.

Plot G. Ablative Skirt Temperatures

X-Axis: Time (sec) 0 to 560 seconds for duration test.

Y-Axis: TAS-6A, TAS-6C, TAS-7.

Plot H. Special Thrust Chamber Parameters

X-Axis: Time (sec) FS_1 to FS_2

Y-Axis: PoJ3, PfJ1, Pci1, Pc5C, TfJ2, Tci1, ToJ-1, MRSA.

9.3, Test Records and Data (cont.)

9.3.6 Final Test Data

Following each test, two copies each of the computer data and analog data shall be delivered to Project Engineering.

9.3.6.1 Computer

Tabulated performance data, validated and qualified, shall be delivered approximately 24 hours following each test.

9.3.6.2 Analog Data

Final analog data summary sheets shall be delivered approximately 48 hours following each test.

(a) The following data will be inlcuded on the Analog Data Sheets for YLR87-AJ-11 engines.

a. Type start
b. FS_1 to ignition
c. FS_1 to P_c spike
d. P_c spike maximum
e. SSC $\dot{W}_B$
f. PgSSC/PXG-0 average
g. SSC/PXG-0 duration
h. FS_1 to PGSSC/PXG-0 initial rise
i. FS_1 to PfJGG secondary rise
j. FS_1 to PoJGG secondary rise
k. FS_1 to GG ignition (PTi or PcGG secondary rise)
l. FS_1 to PoD initial rise
m. FS_1 to PfD initial rise

9.3, Test Records and Data (cont.)

n. FS_1 to PojlA initial rise
o. FS_1 to Pfjl initial rise
p.
q. FS_1 to LTCV-io
r. LTCVo
s. FS_2 to LTCV-ic
t. LTCVc
u. DC voltage, starting and operating
v. P_c overshoot (psig)
w. P_c step duration
x. P_c at PCPS-B make or break (psig)
y. P_c at TCPS-C make or break (psig)
z. FS_1 to TCPS-B make
AA. FS_1 to TCPS-C make
AB. FS_2 to TCPS-B break
AC. FS_2 to TCPS-C break
AD. Duration of test, FS_1 to FS_2
AE. Total gimbal duration, sec (both pitch and yaw)
AF. Gimbal maximum rate, cps (pitch and yaw)
AG. Gimbal maximum displacement, degrees (pitch and yaw)
AH. Gimbal periods (FS_1 + XX.XXX sec to XX.XXX sec, all periods)
AI. Gimbal maximum velocity (ptich and yaw)
AJ. Gimbal maximum acceleration, rad/sec^{-2} (pitch and yaw)
AK. Test date
AL. Engine serial number
AM. Test stand
AN. Time of test
AO. Test number
AP. A_T CC throat measured
AQ. A_T CC exit (non-skirt tests)
AR. Ae ablative skirt exit ID measured

9.3, Test Records and Data (cont.)

(b) On all tests when PgSSC is monitored, calculate W_b per present Computer Program, Job 337. Supply two (2) copies to Project Engineering.

(c) A HSA tabulation Job No. 2901, Plot No. 2902 and a Visicorder recording shall be run of all data on the Ampex tape. Calibrate the Visicorders to 150 psi per inch for all high frequency pressure data. Adjust recorder speed as follows:

Record No. 1	1-Pc6B, 1-Pc7F, 1-Pfj-1A	FS_1 to FS_1 + 2.0 sec at 320 IPS Midpoint -10 sec to Midpoint +10 sec at 320 IPS
Record No. 2	2-Pc6B, 2-Pc6F, 2-Pfj-1A	FS_2 - 2.0 sec to FS_2 at 320 IPS Remainder of test at 3.2 IPS
Record No. 3	1-GTPA-1Y, 1-GRPA-2X, 1-GTPA-3Z, 1-GTPA-4Z, 1-NT (raw), FS/TC	Filtered 500 cps lowpass and raw FS_1 to FS_1 + 5.0 sec at 32 IPS 1.0 sec burst every 50 sec at 32 IPS
Record No. 4	2-GTPA-1Y, 2-GTPA-2X, 2-GTPA-3Z, 2-GTPA-4Z, 2-NT (raw), FS/TC	FS_2 - 1.0 sec to FS_2 + 2.0 sec at 32 IPS Remainder of test at 3.2 sec
Record No. 5	Remaining data not recorded on Records No. 1 through No. 4	Playback rates same as No. 1 and No. 2 unless specified otherwise on Test Request supplement

10.0 QUALITY CONTROL OPERATIONS

10.1 INSPECTION

Quality Control will provide coverage for the following:

10.1.1 Receiving Inspection

10.1.2 Pre and posttest visual inspections

10.1.3 Witness operations when requested by Test Operations/Test Request Supplements and/or Project Engineering.

10.1.4 Document discrepancies on IR's as required. Notify Project Engineering when discrepancies are noted.

10.2 QUALITY ENGINEERING

10.2.1 Review test planning. Make recommendations as required.

10.2.2 Provide one (1) copy of all IR's to Project Engineering prior to each test. Provide one (1) copy of parts removal records prior to each test. Supply Project Engineering with information as required.

10.2.3 Monitor test accept/reject/inspection criteria as specified in Test Requests, engineering drawings or specifications. This includes a discharge line bellows measurement per standard procedure.

11.0 ABLATIVE SKIRT HANDLING

11.1 Ablative skirt will arrive in Test Area as required. Visual receiving inspection is required. Notify Project Engineering when ablative skirt is available for weighing.

11.2 Installation of ablative skirt will be accomplished per normal Test Area procedure and applicable installation drawings.

LUBRICANT REQUIREMENTS

Location	Lubricant
Threaded surfaces in contact with fuel or oxidizer	DC-11 high vacuum grease (AGC-44108)
Gaskets and packings in contact with fuel or oxidizer	DC-11 high vacuum grease (AGC-44108)
Threaded surfaces in hot gas system and pipe thread gearbox fittings	Fel Pro C-5A (AGC-44110)
Flexitallic gaskets in hot gas system	GM cement (formerly Cadillac) (AGC-44129)
Threaded surfaces not in contact with fuel or oxidizer	Lox-Safe (AGC-44053)
Fittings, threaded surfaces, seals, and packings in lube oil system	Lubricating oil, synthetic base (AGC-44218)
Electrical threaded connections	DC-11 high vacuum grease (AGC-44108)
Haskell seals	DC-11 high vacuum grease (AGC-44108)
Thrust Chamber Exit Flange	Inert thread compound, Molybdenum Disulfide type (AGC-44035)
Ablative Skirt Forward Flange	Heat Resistant Sealing Compound (AGC-44068)

ALLOWABLE LEAKAGE RATES

Item	Test Pressures	Allowable Leakage	Reference Paragraph
Fuel System	50 ± 5 psig	2 psig in 5 minutes exclusive of pump seal leakage. No external leakage allowable by liquid leak detection method.	3.5.3.1
Oxid System	50 ± 5 psig	2 psig in 5 minutes exclusive of pump seal leakage. No external leakage allowable by liquid leak detection method.	3.5.3.1
P_c5	850 ± 15 psig	(1) Zero decay in 5 minutes	3.5.3.2
Hot Gas System	50 ± 5 psig	No external leakage allowable by liquid leak detection method. Zero decay in 5 minutes. (0.5 psi in five minutes permitted if test is impending.) NOTE: NOt necessary to repeat leak check after installation of the solid start cartridges.	3.5.3.3
Autogenous Systems	50 ± 5 psig	(1) Zero decay in 5 minutes. (2) No internal gas cooler leakage allowable for 10 minutes by bubble leak check method.	3.5.3.4
Elec. Controls	$10 {+1 \atop -0}$ psig	Zero decay after 2 minutes (if leakage is noted, apply a 5 to 10 psig N_2 purge to the electrical harness throughout the test).	3.5.3.5

ALLOWABLE LEAKAGE RATES

Item	Test Pressures	Allowable Leakage	Reference Paragraph
COMBUSTION CHAMBER			
External Leakage	With coolant jacket and combustion zone filled with water and pressurized to 50 ± 5 psig.	None	3.5.3.6
Internal Leakage	With coolant jacket filled with water to downstream level of the torus and under static head.	None	3.5.3.6
Propellant Supply System (TCA and GGA)	50 ± 5 psig	No leakage allowable by liquid leak detection method.	3.5.3.7
Oxid Pump Seal	50 ± 5 psig	900 cc/min (least leakage)	3.5.3.8
Fuel Pump Seal	50 ± 5 psig	900 cc/min (least leakage)	
Oxid Gearbox Seal	15 ± 1 psig	300 cc/min (least leakage)	
Fuel Gearbox Seal	15 ± 1 psig	300 cc/min (least leakage)	
Turbine Seal	50 ± 5 psig	750 cc/min (least leakage)	

TITAN IIIM
BASIC INSTRUMENTATION
REQUEST

FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
Pressures													
Pot	0-200	X		X									
ΔPot	0-50		X	X									Range 0-25 lb on Brown
(1) Pos 36A	0-100			X									Outboard
(2) Pos 36A	0-100			X									
(1) Pos 36B	0-200		X	RS			X						500 psig Xducers
(2) Pos 36B	0-200		X	RS	X								
(1) Pod	0-1500		X	RS			X	X					0-2000 Range on Browns
(2) Pod	0-1500		X	RS	X			X					
(1) PoJ-3	0-1500			X			X	X					
(2) PoJ-3	0-1500			X	X			X					
(1) PoBTV	0-1500			RS		X							
(2) PoBTV	0-1500			RS		X							
(1) PoJGG	0-1000			RS		X		X					
(2) PoJGG	0-1000			RS		X		X					
Pft	0-100	X		X									
ΔPft	0-20		X	X									Range 0-15 lb on Brown
(1) Pfs-41A	0-100		X	X									Outboard
(2) Pfs-41A	0-100		X	X									
(1) Pfs-41B	0-500			RS			X						
(2) Pfs-41B	0-500			RS	X								
(1) Pfd	0-1500		X	RS			X	X					Range 0-2000g on Browns
(2) Pfd	0-1500		X	RS	X			X					
(1) Pci	0-1500			X			X						Elbows
(2) Pci	0-1500			X	X								
(1) PfJ-1	0-1500			RS			X	X					
(2) PfJ-1	0-1500			RS	X			X					
(1) PfBTV	0-1500			RS		X							
(2) PfBTV	0-1500			RS		X							
(1) PfJGG	0-1000			RS		X		X					
(2) PfJGG	0-1000			RS		X		X					
(1) Pc5B-1	0-1000		X	RS			X						
(2) Pc5B-1	0-1000		X	RS	X								

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FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
(1) Pc5B-2	0-1000			RS		X	X						
(2) Pc5B-2	0-1000			RS	X	X							
(1) Pc5C	0-1000		X	DRS			X	X	X				Use Redcor Amp.
(2) Pc5C	0-1000		X	DRS	X			X	X				
(1) PcGG	0-1000			RS			X						
(2) PcGG	0-1000			RS	X								
(1) Pti	0-1000		X	RS			X	X					
(2) Pti	0-1000		X	RS	X			X					
(1) Pgssc	0-4000			RS				X	X				SSC Start Only
(2) Pgssc	0-4000			RS				X	X				
(1) PxG-7	0-1500			RS				X	X				
(2) PxG-7	0-1500			RS				X	X				N_2 Start Only
PxG-0	0-4000		X	X					X				
(1) PgGB	0-100	X		X			X						
(2) PgGB	0-100	X		X	X								
(1) Pld	0-100	X		X			X						
(2) Pld	0-100	X		X	X								
(1) ΔP1P	0-100	X		X			X						Range 0-50 Visual
(2) ΔP1P	0-100	X		X	X								Pld - PgGB
(1) ΔP1F	0-100			X			X						PLOLHE - PgGB
(2) ΔP1F	0-100			X	X								
PopVi	0-1500			X		X							
PopOi-A1	0-1000			X		X							
PopOi-A2	0-1000			X									
PopOo	0-500			X									
PfpOi-A	0-500			X		X							
PfpOi-	0-500			X									
PfpOo	0-500			X									
(1) ΔPaGY	±3500			X								X	
(2) ΔPaGP	±3500			X								X	Gimbal Only
(2) ΔPaGY	±3500			X								X	
(2) ΔPaGP	±3500			X								X	
PHE	0-4000	X		X									
Pld	0-4000	X		X									Gimbal Only
PTCOP	0-1000	X		X									
PTCFP	0-1000	X		X									

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BASIC INSTRUMENTATION
REQUEST

FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
(1) PwDP	0-1000	X		X									
(2) PwDP	0-1000	X		X									
PGfPR	0-200	X		X									
PGfPM	0-200	X		X									
PGoPR	0-200	X		X									
PGOPM	0-200	X		X									
FA-T	0-500K			RS		X							
FB-N	0-125K			X									
FB-E	0-125K			X									
FB-S	0-125K			X									
FB-W	0-125K			X									
Flows and Speeds													
(1) FMOS-1	600 lb/sec		X	RS			X						
(1) FMOS-2	600 lb/sec			X				X					
(2) FMOS-1	600 lb/sec		X	RS	X								
(2) FMOS-2	600 lb/sec			X				X					
(1) FMfs-1	400 lb/sec		X	RS			X						
(1) FMfs-2	400 lb/sec			X				X					
(2) FMfs-1	400 lb/sec		X	RS	X								
(2) FMfs-2	400 lb/sec			X				X					
(1) NT	30,000 rpm		X	RS			X	X				X	
(2) NT	30,000 rpm		X	RS	X			X				X	
FMfBV	25 lb/sec	X											
ADC Digital													
(1) FMVos				D-1									
(2) FMVos				D-2									
(1) FMVfs				D-3									
(2) FMVfs				D-4									
(1) NTVS-D				D-5									
(2) NTVS-D				D-6									

TITAN IIIM
BASIC INSTRUMENTATION REQUEST

FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
RTT- °F													
(1) TosFM	0-200			X									
(2) TosFM	0-200			X									
(1) TfsFM	0-200			X									
(2) TfsFM	0-200			X									
Tfp0i-B	0-400			X									
Tfp0i-B	0-500			X									
Thermocouples - °F													
(1) TTi-1	0-2500		X	X									Kill at 1700°F
(1) TTi-2	0-2500			X									
(2) TTi-1	0-2500		X	X									Kill at 1700°F
(2) TTI-2	0-2500			X									
(1) TAS-6A	0-500			X									
(2) TAS-6A	0-500			X									
(1) TAS-6C	0-500			X									Skirt Test Only
(2) TAS-6C	0-500			X									
(1) TAS-7	0-500			X									
(2) TAS-7	0-500			X									
(1) Tos-36	0-200			X									
(2) Tos-36	0-200			X									
(1) Tfs-41	0-200			X									
(2) Tfs-41	0-200			X									
(1) TosFM	0-200			X									
(2) TosFM	0-200			X									
(1) TfsFM	0-200			X									
(2) TfsFM	0-200			X									
(1) Tci-1	0-200			X									
(2) Tci-1	0-200			X									
(1) ToJ-1	0-200			X									
(2) ToJ-1	0-200			X									

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BASIC INSTRUMENTATION
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FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
(1) TfJ-2	0-400			X									
(2) TfJ-2	0-400			X									
ToPOi-A	0-500			X									
TfPOi-A	0-400			X									
ToPOo	0-500			X									Delete for
TfPOo	0-400			X									Skirt Tests
(1) TB-1 thru -5, -7 thru -11	0-500			(10) X									Use Spring Housing and TC PN 1129464 in TB-5
(2) TB-1 thru -5, -7 thru -11				(10) X									
(1) TB-6	0-500		X	X									Use TC PN 1130277-11
(2) TB-6	0-500		X	X									Kill at 500°
Other													
(1) LTCV-A	0-100%						X	X					
(2) LTCV-A	0-100%				X			X					
(1) LTCV-B	0-100%								X		X		
(2) LTCV-B	0-100%								X		X		
(1) LGY	±6°					X					X		
(2) LGY	±6°					X					X		Gimbal Test Only
(1) LGP	±6°					X					X		
(2) LGP	±6°					X					X		
(1) OST	*ST							X	X				26,500 + 250 rpm
(2) OST	ST							X	X				26,500 ± 250 rpm
(1) ISC-A	ST							X	X				
(2) ISC-A	ST							X	X				Solid Cartridge
(1) ISC-B	ST								X				Start Only
(2) ISC-B	ST								X				
(1) OTVS	ST								X				
(2) OTVS	ST								X				
TCOPV	ST								X				
TCFPV	ST								X				

*ST = Switch Trace

TITAN IIIM
BASIC INSTRUMENTATION
REQUEST

FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
(1) TCVPSV	ST								X	X			
(2) TCVPSV	ST								X	X			
MXGVTPA	*ST							X	X	X			
OST Lockout	ST								X				
ESS	ST								X				
FS1 - FS2	ST		X	X	X	X	X	X	X			X	Time Code on OSC and Tape
FS2 Remote	ST								X				
(1) TPAXGV	ST							X	X	X			N_2 Start Only
(2) TPAXGV	ST							X	X	X			
(1) TCPS-B (C)	ST 34								X				
(1) TCPS-B (0)	ST 36								X				
(1) TCPS-C (C)	ST 21								X				
(1) TCPS-C (0)	ST 22								X				
(2) TCPS-B (C)	ST 35								X				
(2) TCPS-B (0)	ST 43								X				
(2) TCPS-C (C)	ST 25								X				
(2) TCPS-C (0)	ST 26								X				
(1) FTVS	ST 23								X				
(2) FTVS	ST 24								X				
High Frequency													
(1) Pc6B (H)K	0-1000											X	
(2) Pc6B (H)K	0-1000											X	
(1) Pc6F (H)K	0-1000											X	
(2) Pc6F (H)K	0-1000											X	
(1) PfJ-1A (F)M	0-1500											X	
(2) PfJ-1A (F)M	0-1500											X	
(1) GTPA-1Y	300G RMS											X	
(2) GTPA-1Y	300G RMS											X	
(1) GTPA-2X	300G RMS											X	
(2) GTPA-2X	300G RMS											X	

*ST = Switch Trace

TITAN IIIM
BASIC INSTRUMENTATION
REQUEST

FUNCTION	RANGE	VISUAL	BROWN	ADC	R-1	R-2	R-3	R-4	R-5	BERKELEY	SANBORN	AMPEX	REMARKS
(1) GTPA-3Z	300G RMS											X	
(2) GTPA-3Z	300G RMS											X	
(1) GTPA-4Z	300G RMS											X	
(2) GTPA-4A	300G RMS											X	
(1) SGY-A												X	
(2) SGY-A												X	
(1) SGY-B												X	
(2) SGY-B												X	
(1) SGP-A												X	Non-gimbal tests range per calib. sheets
(2) SGP-A												X	
(1) SGP-B												X	
(2) SGP-B												X	

APPENDIX C

DAILY TEST LOG

PRECEDING PAGE BLANK - NOT FILMED.

TEST SERIES: 3051-D07-1A-2XX

DATE	RUN NO.	REMARKS
7 Dec 1967		Received T-IIIM Demo Engine LR87-AJ-11 S/N 14. Performed Receiving Inspection on Engine and installed Engine in test stand G-2. Removed Combustion Chamber S/N 017 from S/A-1, and installed CC S/N 019. Removed Fuel Autogenous Hot Gas Cooler P/N 1130712-19A, S/N 750 and installed Hot Gas Cooler P/N 284889-19G, S/N 753. Still photo Request #1452 for Hot Gas Cooler S/N 753, and CC S/N 019, after installation. Removed dummy FPBO and installed FPBO, I.D. 0.430. Removed dummy OPV and installed OPV S/N 380, Kv .0824. Removed S/A-2 ODO; none required per Pre-Dec. Following components declared obsolete pre-test: Autogenous Hot Gas Cooler P/N 284899-19, S/N 753 S/A-1 Turbine 1st rotor P/N 1130983-1, S/N 164 S/A-1 Turbine 2nd rotor P/N 1130120-3, S/N 799 S/A-2 Turbine 1st rotor P/N 1130119-1, S/N 607 S/A-2 Turbine 2nd rotor P/N 1130120-3, S/N 797 Interconnecting Box Assy, P/N 1132570-19, S/N 001
19 Dec 1967		Completed N2 start calibration flow check and Engine sequence functional. Completed installation of all temperature and pressure transducers. Pre-test Still Photo Request Nos. 0581, 1452, 1762 and 1842 of engine test setup. Loaded propellant tanks, and conditioned Fuel to 66°F and Oxidizer to 64°F. Completed all test stand and Engine pre-fire checks and services.
20 Dec 1967 2300 Hrs.	201	Conducted Balance Adjustment Test for a duration of 19.62 seconds. Classification Exclusion Prior (E.P.) Shutdown due to decay of Deflector-Plate water pressure. Post-test inspection revealed 6-inch Dressler coupling in Deflector plate feeder line failed. Post-test Engine inspection showed S/A-2 CC S/N 20 Epon cracked, and wire wrap loose.

DATE	RUN NO.	REMARKS
		Post-test Engine leak checks showed following minor leakage: S/A-1 Oxid Pump Seal approx 75 cc/min S/A-2 Oxid pump Seal approx 50 cc/min Liquid leak detect showed slight fuzz on both S/A-2 GGA/TM flanges. No fuel or Hot Gas leakage noted on S/A-2 CC.
		Post-test Over-all still photo view of Engine on Req. #7892. Hot firing motion picture roll film Nos. 76842, 76843, 76844.
		Chemical Lab analysis and pressure records indicated Lube Oil Cartridge Filters function normal.
26 Dec 1967		Completed post-fire checks and service procedures. Lowered both Subassembly Combustion Chambers by the long-bolt method and replaced inner and outer Raco seals, P/N's 701773, 701771 respectively. Still photos of Racos on Req. #2295.
27 Dec 1967		Completed S/A-1 TPA Turbine Rotor removal and replacement: Removed from TPA S/N 008; 1st Rotor ....P/N 1130983-1, S/N 164 2nd Rotor ....P/N 1130120-3, S/N 799 Installed in TPA S/N 008; 1st Rotor ....P/N 1130983-1, S/N 622 2nd Rotor ....P/N 1130974-1, S/N 002
28 Dec 1967		Completed S/A-2 TPA Turbine Rotor removal and replacement: Removed from TPA S/N 010; 1st Rotor ....P/N 1130119-1, S/N 607 2nd Rotor ....P/N 1130120-3, S/N 797 Installed in TPA S/N 010; 1st Rotor ....P/N 1130983-1, S/N 624 2nd Rotor ....P/N 1130974-1, S/N 003

DATE	RUN NO.	REMARKS
		Completed following engine balance change: Removed FPBO .430 and installed FPBO .410 Removed FPN .510 and installed FPN .470 Removed S/A-1 FBTV S/N 714, Kv .360, and installed S/N 603, Kv .355
29 Dec 1967		Loaded propellant tanks and conditioned Fuel to 64°F and Oxid to 62°F.
		The following components were declared obsolete pre-test: Hot Gas Cooler P/N 284899-19, S/N 753 Interface Connector Box assy P/N 1132570-19, S/N 001 The S/A-2 Combustion Chamber P/N 1130174-79, S/N 020 was declared damaged pretest.
		Completed all test stand and Engine pre-fire checks and services.
29 Dec 1967 2030 Hrs.	202	Conducted Demonstration Performance Evaluation Test for a duration of 200.944 seconds. Classification: Successful.
29 Dec 1967		Completed TCVPSV flush and purge, lube oil drain and flush, and autogenous service. Removed both Sub-assembly Superheaters and performed cleaning of Superheaters in B-Area. Post-fire visual inspection revealed no additional damage. Hot firing motion picture roll film Nos. 80014, 80015, 80016.
2 Jan 1968		Post fire Engine leak checks showed the following leakage: S/A-2 Oxid pump seal..........40 cc/min S/A-2 Turbine seal ....275 cc/min Liquid Leak-Detector Fuzz at GG/TM flange, both Sub-assembly. S/A-2 Inj./CC flange, fuzz.
		Removed 1st and 2nd stage turbine rotors from both Subassembly TPA's per prefire disposition on Inspection Report 438439, for inspection and further disposition.

DATE	RUN NO.	REMARKS
3 Jan 1968		Performed "Torque-to-tighten" check on Inj/CC flange bolts, on both S/A. All bolts were within the specified torque. Removed and replaced inner and outer Paco seals at Inj/CC flange on both sub-assemblies per the long bolt method. Still photos of Raco seals on Req. #2753.
		Received S/A-1 Turbine rotors S/N 622 1st rotor, and 002 2nd rotor, back from Precision Assembly inspection.
		S/A-2 turbine rotors S/N 624 and S/N 003 failed inspection and were not accepted for reuse.
4 Jan 1968		Completed S/A-1 Turbine kit assembly with 1st Rotor S/N 622, and 2nd Rotor S/N 002, and installed Superheater.
		Records review and Chemical Lab analysis showed both sub-assembly Lube Oil Cartridge Filters performance within limits.
9 Jan 1968		Received S/A-2 Turbine 1st Rotor S/N 638 and 2nd Rotor S/N 008, and completed Turbine kit assembly, and Superheater installation.
		During TCPS pressure checks internal Engine wiring reversal between 2-TCPS-B and 2-TCPS-C was discovered. The wiring was corrected and all previous TCPS make and break values were corrected.
		Completed test stand and Engine sequence functionals, loaded propellant tanks, and conditioned Fuel to 60°F and Oxid to 61°F.
		Removed FPN .470 and installed FPN .440. Removed OPV .0824 and installed OPV .0837.
		The following components were declared obsolete pre-test: Autogenous Hot Gas Cooler P/N 284899-19, S/N753 Interface Connector Box Assy P/N 1132570-19, S/N 001.

DATE	RUN NO.	REMARKS
		S/A-2 CC P/N 1130174-79, S/N 020 was declared damaged pre-test
10 Jan 1968		Completed all test stand and Engine prefire checks. Applied adhesive type tape to S/A-2 CC loose wire wrap per I.R. 448729.
10 Jan 1968	203	Conducted Demonstration Performance Evaluation Test for a duration of 200.706 seconds. Classification: Successful.
		Hot firing motion picture roll film Nos. 80090, 80091, 80092.
		Post- est inspection revealed increase in S/A-2 CC S/N 020 loose wire wrap condition, and crack in interior of inlet flange.
		Post fire leak checks showed: S/A-1 turbine seal leakage at 150 cc/min., and S/A-2 turbine seal leakage at 220 cc/min.
		Completed Lube Oil service and Autogenous cleaning service, and PSV flush and purge.
		Removed S/A-1 Turbine Rotors for inspection.
11 Jan 1968		During removal of S/A-2 Turbine Rotors for inspection, the Turbine Rotor Bolt was discovered only finger-tight.
		S/A-2 TPA S/N 010 Turbine Rotors and Bolt were sent to Precision Assembly for further inspection.
12 Jan 1968		Removed S/A-2 CC S/A 020, took still photo of cracked inlet flange on photo Req. #3507, and shipped CC S/N 020 to Manufacturing Div. on I.R. 438453 for repair and further disposition.
15 Jan 1968		Removed S/A-2 TPA S/N 010 and shipped to Manufacturing Division for Highspeed Shaft check and Turbine re-assembly.

DATE	RUN NO.	REMARKS
		Records and Chemical Lab analysis showed Lube Oil Cartridge Filters performance within limits.
16 Jan 68		Removed and replaced S/A-1 Inj/CC race seals by the long bolt method.
17 Jan 68		Completed S/A-1 Turbine Kit re-assembly and Superheater installation.
		Dye-pen inspected S/A-1 CC S/N 019 inlet flange with no cracks visible.
31 Jan 68		Received TPA S/N 010
1 Feb 68		Completed installation of S/A-2 TPA S/N 010 on Engine. Installed CC S/N 018 on S/A-2 for decontamination purposes. Removed Engine from test stand and transferred to B-Area for decontamination.
2 Feb 68		Engine decontamination completed and Engine reinstalled on test stand.
5 Feb 68		Removed dummy CC S/N 018 from Engine and returned to Manufacturing Division. Continued Engine installation.
6 Feb 68		Installed Gimbal Stiff-Links to measure Discharge Line Bellows.
27 Feb 68		Completed application of 7/32" thick x 3/8" wide cork strips on inside of Refrasil Insulation panels, for S/A-1 only, to provide stand-off space between Refrasil and Ablative Skirts. Still photo job #12626.
		Completed installation of new type Oxid Autogenous Interface bracket and coupling, P/N's 1133676-9 and 1133775-1 resp., per Test Request Supplement #13. Still Photo Job #12626.
1 Mar 68		Received and installed S/A-2 CC S/N 017 on Engine. Still Photo Job #13821.
6 Mar 68		Removed S/A-2 Lube Oil Cooler P/N 1130728-3, S/N 013 per I.R. #458409 disposition due to dent in bottom of Cooler shell. Installed Lube Oil Cooler P/N

DATE	RUN NO.	REMARKS
		1130728-7, S/N 006. Still Photo Job #13821.
7 Mar 68		Completed test stand and Engine sequence-functional, and TCPS functional.
		Installed Special unshielded thermocouple at S/A-1 Turbine manifold blank flange with the nomenclature TTM-B.
		Installed special pressure boss fittings on Lube Oil Cooler Fuel Coolant inlet ports, with nomenclature 1-PcLHE and 2-PcLHE.
		Completed leak checks. Performed Turbine Manifold Gearbox static steal leak check on S/A-1 using Freon TF commercial grade as leak detector, and used Soap liquid leak detector, and water followed by alcohol flush, and nitrogen purge on S/A-2. This procedure requested on SATRS #14.
		Completed all test stand and Engine prefires.
		Completed Gimbal system functional.
8 Mar 68		Installed Ablative Skirt P/N 1129770-19A, S/N 025 on S/A-1. Installed Ablative Skirt P/N 1129770-19A, S/N 037 on S/A-2. Took 70mm sequence photos.
11 Mar 68		Installed Martin Co. Refrasil Insulation with cork strip stand-off spacers on S/A-1, and Refrasil Insulation without cork strips on S/A 2. Took 70mm sequence photos.
11 Mar 68 1723 Hours	204	Conducted Demonstration Performance Evaluation Test with Ablative Skirts, Refrasil Insulation, and Gimballing. Duration: 115.438 seconds. Command shutdown due to rapid decrease in S/A-2 performance. Motion Picture roll film Nos. 80369, 80370, 80371.
		Removed Refrasil Insulation and Ablative Skirts from both Subassemblies, and stored in G-Area Shop Buildup Room.
		Postfire TPA torque checks revealed S/A-2 TPA seized; i.e., would not rotate. Removed S/A-2

DATE	RUN NO.	REMARKS
		Superheater and TPA S/N 010. Shipped TPA S/N 010 to Precision Assembly on Rejection I.R. #438486.
		Completed Fuel Autogenous Hot Gas Cooler Cleaning.
12 Mar 68		Removed S/A-1 Superheater and cleaned both S/N superheaters, S/N's 376, 378 in B-Area.
		Removed Fuel Autogenous Hot Gas Cooler S/N 753, due to internal leakage, per I.R. disposition, and shipped to Manufacturing Division.
		Completed S/A-1 Lube Oil service.
		Records and Chemical Lab analysis indicate Lube Oil Cartridge Filters performance within limits.
13 Mar 68		Removed both Subassembly TCA's from Engine and disassembled in G-Area Buildup Room.
		Took photos of S/A-1 Injector S/N 697 on Req. #14252 of Injector Baffles weld cracks.
14 Mar 68		Dye-pen inspected S/A-2 Injector S/N 696, and took photo of baffle weld cracks on Photo Req. #14277.
		Shipped Injectors S/N 696 and 697 to Manufacturing Division for further inspection and disposition.
		Removed S/A-1 TPA Turbine Rotors S/N 637, and 005; 1st and 2nd stage resp., and shipped to Precision Assembly for inspection and further disposition.
20 Mar 68		Shipped S/A-1 TPA Turbine 2nd Nozzle S/N 058 to Precision Assembly, for inspection and special dimensional checks.
22 Mar 68		Installed Fuel Autogenous Hot Gas Cooler S/N 775.
25 Mar 68		Assembled Injector S/N 697, and CC S/N 019 for S/A-1.

DATE	RUN NO.	REMARKS
26 Mar 68		Installed S/A-1 TCA on Engine. Assembled S/A-2 TCA with Injector S/N 696, and CC S/N 017.
		Removed S/A-1 Lube Oil Cooler S/N 012 and installed S/N 116.
29 Mar 68		Installed S/A-1 Turbine Seal and running ring, and Turbine Manifold, on TPA S/N 008.
		Removed S/A-1 OBTV S/N 1433, Kv .0253 and installed OBTV S/N 868, Kv .0261.
		Removed S/A-1 FBTV S/N 603, Kv .3550 and installed FBTV S/N 717, Kv .383.
		Removed S/A-2 OBTV S/N 1453, Kv .0268 and installed OBTV S/N 937, Kv .0282.
		Removed S/A-2 FBTV S/N 605, Kv .3917 and installed FBTV S/N 716, Kv .408.
1 Apr 68		Completed S/A-1 Turbine Kit Assembly with following parts: 1st Rotor P/N 1154300-5, S/N 006 2nd Rotor P/N 1130974-3, S/N 895 2nd Nozz P/N 260825-11, S/N 665
2 Apr 68		Installed TPA S/N 006 on S/A-2.
		Installed S/A-2 TCA on Engine with Inj S/N 696, and CC S/N 017.
2 Apr 68		Installed S/A-1 Superheater.
3 Apr 68		During attempted installation of S/A-2 TPA bearing thermocouple TB-7 on TPA S/N 006, the boss plug fractured. TB-7 was deleted for next test.
		Completed test stand and Engine sequence-functional and TCPS functional, Instrumentation setup and pre-fire leak checks.

DATE	RUN NO.	REMARKS
4 Apr 68		Completed all test stand and Engine prefire checks and services.
		The following components were declared obsolete Pre-test:
		Interface connector box P/N1132570-19, S/N 001 TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N265382-19, S/N's 476,478 Fuel Discharge lines P/N256866-19, S/N's 054, 131
		S/A-1 Turbine 1st rotor P/N 1154300-5, S/N 006 declared experimental Pre-Test.
5 Apr 68 1415 hours	205	Conducted Balance Adjustment Test for a duration of 20.88 seconds. Classification: Exclusion-Prior. No anomalies noted.
		Completed leak checks, Lube Oil service, Hot Gas Cooler cleaning, and PSV flush and purge.
6 Apr 68		Completed Injector/CC Race seal replacement on both Subassemblies by the long bolt method.
8 Apr 68		Removed broken plug from TB-7 boss on S/A-2 TPA S/N 006, and installed TB thermocouple.
		Completed Engine balance change as follows: Installed S/A-1 ODO 3.970, was: NONE Installed S/A-2 ODO 3.900, was: NONE Removed S/A-1 FDO 3.127, now: NONE Installed S/A-1 OBTV S/N1453, Kv .0268, was S/N 868, Kv .0261.
		Completed test stand and Engine sequence functional.
9 Apr 68		Completed Prefire leak checks, and installed Ablative Skirt S/N 025 on S/A-1.
10 Apr 68		Installed Ablative Skirt S/N 037 on S/A-2. Ablative Skirts S/N 025 and 037 were utilized on Test #204 for 115 seconds.
		Records indicate Lube-Oil Cartridge Filters performance within limits.

DATE	RUN NO.	REMARKS
10 Apr 68		Installed Martin Co. Refrasil Insulation covers which were utilized on Test #204. Completed all test stand and Engine prefire checks and services. The following components were declared obsolete pre-test: Interface connector box P/N 1132570-19, S/N 001. TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N265382-19, S/N's 476, 478 Fuel Discharge lines P/N256866-19, S/N's 054, 131 Ablative Skirts S/N's 025 and 037 were pre-declared overage on time. S/A-1 Turbine 1st Rotor P/N 1154300-5, S/N 006 was pre-declared experimental.
10 Apr 68 1920 hours	206	Conducted Demonstration Performance Evaluation Test for a duration of 201.040 seconds, with Ablative Skirts, Refrasil Insulation, and Gimballing. Classification; Successful Motion Picture roll film Nos. 80493 through 80497, incl. Removed both Subassembly Refrasil covers and Ablative Skirts S/N 025 and 037. Shipped Ablative Skirts to Building 2002 for further disposition. Commenced Hot Gas Cooler cleaning, and LubeOil service.
11 Apr 68		Completed Hot Gas Cooler cleaning and leak checks. Removed Superheaters and shipped to B-Area for cleaning. Removed both Subassembly TCA's and disassembled. Shipped injectors S/N 696 and 697 to Building 2002 for baffle-root-weld crack repair. Completed Hot Gas Cooler cleaning.

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DATE	RUN NO.	REMARKS
29 Apr 68	207	Conducted NPSH Evaluation test for a duration of 200.722 seconds. Classification: Success Test Objective: Primary: Oxidizer minimum NPSH to be at 44 feet for approx 10 seconds. Secondary: Fuel minimum NPSH to be at 43 feet concurrent with Oxid at 44 ft. Also, Oxid at 35 ft. with fuel normal. Low target pressures were obtained, but suction pressures never returned to normal due to tank ullage and test stand N_2 pressurization capacity. Motion Picture roll film Nos. 18007.
30 Apr 68		Completed Fuel Autogenous Hot Gas Cooler cleaning and removed both Subassembly Superheaters for cleaning. Completed Superheater cleaning. Post-fire visual inspection and CC static pressure water leak check revealed S/A-2 CC S/N 019 has four (4) tube weld leaks at inlet flange, interior. These are pinhole leaks but the leak at tube #28 leaks at the rate of approx one (1) drop/sec. The other three (3) leaks are ccw (looking-up) and approx four (4) inches apart, starting with Tube #28. MRB disposition of IR on S/A-2 CC S/N 019 pinhole leakage at inlet flange tube welds is Accept As-Is.
1 May 68		Received and attempted to install New type Inj/CC inner Raco seal P/N 10050-21.776A, on S/A-1. The results of two (2) attempts to install Inj/CC inner Raco seal P/N 10050-21776A on S/A-1 was Teflon protrusion into the combustion zone, between Inj and CC flanges. Removed S/A-1 Raco Seal P/N 10050-21.776A and installed standard P/N 701773 (inner) and 701771 (outer).
2 May 68		Completed S/A-2 Inj/CC Raco Seal removal and replacement with standard Racos.

DATE	RUN NO.	REMARKS
		Completed Turbine Rotor Bolt inspection on both Subassemblies per TRS #35.
3 May 68		Completed Superheater installation on both S/A.
		Loaded Propellants and conditioned to 60°F.
		Completed balance change as follows: S/A-1 ODO was 3.97 is NONE FDO was None is 3.30 OBTV was .0268 is .0274 FBTV was .383 is .397 S/A-2 ODO was 3.90 is NONE FDO was None is 3.400 OBTV was .0282 is .0298 FBTV was .408 is .432
		Completed pre-fire leak checks and fuzz leakage was accepted by MRB decision for both S/A at T.M./2nd Nozz and at T.M/GG.
		The following components were declared obsolete, pre-test: Interface connector box P/N 1132570-19, S/N 001 TPA P/N 1131352, S/N 006. Oxid Discharge lines P/N 265382-19, S/N's 476,478 Fuel Discharge lines P/N 256866-19, S/N's 054, 131 Lube oil cooler P/N 1130728-3, S/N 116 (Tpa S/N 008, S/A-1)
4 May 68	208	Conducted Balance Adjustment Test with + 3% Thrust and + 2% MR, for duration of 21.235 seconds. Classification: Success
6 May 68		Completed all postfire checks and services. Removed all instrumentation, purge and drain lines. Removed Engine S/N DEMO-14 from Test Stand and shipped to Manufacturing Division via D-4 for decontamination.
		Discharge Line Bellows dimensional checks to be performed prior to next test on engine.

DATE	RUN NO.	REMARKS
11 June 68		Received Engine Demo-14 from Manufacturing Division and commenced Receiving-Inspection.
12 June 68		Installed Engine Demo-14 on Test Stand G-1 and commenced fabrication of instrumentation brackets.
		Continued Interface plumbing, Helium supply plumbing, and transducer bracketing, and plumbing. Completed Discharge Line Bellows dimensional check.
		Performed Fuel and Oxid Drop test for propellant system contamination check. Check good.
		Performed N_2 Start Calibration-Flow check and Start Timer check.
		IR on Discharge Line Bellows Dimensions dispositioned as continuing discrepancy and Accept-As-Is.
		IR on S/A-1 Inj/CC gap dispositioned as Continuing Discrepancy and Accept-As-Is.
		Installed Gimbal Stiff-Links with strain-gages and welded rod-ends.
		Installed work-horse Lube-Oil Filter Cartridges and filled Lube system.
		Fabricated and installed special fitting for PfCKVi for S/A-1. Fabricated and installed new Electrical Interface Harness for T-IIIM, G-1. Calibrated purges. Loaded propellants into run tanks and conditioned to 36°F.
		Performed Engine balance change as follows: S/A-1 ODO was None is 3.40 FDO was 3.30 is NONE OBTV was .0274 is .0261 FBTV was .397 is .374 (balance change cont'd.)

DATE	RUN NO.	REMARKS
		S/A-2 ODO was None is 3.25 FDO was 3.40 is NONE OBTV was .0298 is .0278 FBTV was .432 is .408
		The following components were declared Obsolete, Pre-test: Interface connector box P/N 1132570-19, S/N 001 TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N 265382-19, S/N's 476, 478 Fuel Discharge lines P/N 256866-19, S/N's 054, 131 Lube Oil Cooler P/N 1130728-3, S/N 116 (TPA S/N 008, S/A-1) Turbine 2nd Nozz P/N 260625, S/N 665 (S/A-1 TPA S/N 008)
		Completed photos of initial test setup on G-1, including, but not limited to: PfCKVi fitting, Autogenous Interface, Gearbox functions, Kistlers and Helium supply, Instrumentation transducers and brackets and over-all engine views. Photo Job No. 24360.
		Completed all normal Test Stand and Engine Pre-fire checks and service.
		Verified both sub-assembly TPA Lube Oil Pumps installed.
July 68 1634 Hrs.	209	Conducted Balance Adjustment Test for a duration of 20.586 sec. Classification: Excl[illegible]a-Prior with no abnormalities.
		Hot firing Motion Picture Roll Film Nos. 8-812, 8-813, 8-814.
		Inspection and records indicate Lube Oil Filters performance within limits.
		Completed all normal Post-fire checks and services.
		Replaced Inj/CC Raco Seals on both Sub-assemblies.

DATE	RUN NO.	REMARKS
		Discharge Line Bellows Dimensional check and S/A-1 Inj/CC gap IR's Continuing Discrepancy dispositioned to Accept-As-Is.
		2-TB-8 questionable on Test -209. Removed and replaced with new thermocouple.
		Installed 1-PC-5C In-Flite Bracket and In-Flite Turbine Speed D.C. Converter.
3 July 68		Installed Martin Co. Fuel Pogo Accumulators on both subassemblies.
		Removed S/A-1 Superheater and performed 2nd rotor and bolt inspection and dimensional checks. Replaced Superheater.
		Added Pogo transducers PFS and PGfTA on fuel accumulators on both subassemblies.
		Pre-fire Pogo Fuel Accumulators photos on Job No. 24840.
		Completed all Test Stand and Engine pre-fire checks and service.
		The following components were declared obsolete, pre-test: Interface connector box P/N 1132570-19, S/N 001. TPA P/N 1131352, S/N 006 Oxid discharge lines P/N 265382-19 S/N's 476, 478 Fuel discharge lines P/N 256866-10, S/N's 054, 131 Lube oil cooler P/N 1130728-3, S/N 116 (TPA S/N 008, S/A-1). Turbine 2nd Nozz P/N 260825, S/N 665 (TPA S/N 008, S/A-1).
		Combustion Chamber P/N 1133311-19, S/N 092 (S/A-2) was declared experimental, Pre-test.
		Loaded and conditioned propellants to 37°F.
		Installed Solid Start Cartridges and Igniters.

DATE	RUN NO.	REMARKS
5 July 68 1916 Hrs.	210	Conducted Peripheral Test with Fuel Pogo Evaluation for a duration of 200.407 seconds and classified success. Piggy-back fuel Pogo Accumulators Test, 3051-D20-1H-001.
		Hot firing Motion Picture Roll Film Nos. 8-0835, 8-0836, 8-0837.
		Completed Hot Gas Cooler cleaning.
		Replaced S/A-2 GG/T.M. and FPBO flange gaskets during leak check.
		Removed both Superheaters and performed Turco bath cleaning.
6 July 68		Replaced Inj/CC Raco Seals on both subassemblies.
9 July 68		Performed Turbine Kit removal and replacement on both S/A due to TTi exceeding 1700°F during shutdown transient and Hot Gas Static-Seal leak repair.
		S/A-1 2nd Nozzle S/N 665 removed, S/N 685 installed. S/A-2 2nd Nozzle S/N 596 removed, S/N 745 installed.
		Transferred PfCKVi from S/A-1 to S/A-2, and obtained still photo on Job No. 25260
		Transferred propellants to run tanks and conditioned to 59°F.
		Removed MMC Fuel Pogo Accumulators and installed standard suction bellows.
		Performed Engine Balance change as follows: S/A-1 ODO was 3.400 is 3.700 FDO was NONE is NONE OBTV was .0261 is .0278 FBTV was .374 is .406 S/A-2 ODO was 3.250 is 3.700 FDO was NONE is NONE OBTV was .0278 is .0299 FBTV was .408 is .426

DATE	RUN NO.	REMARKS
		Completed all Test Stand and Engine Pre-fire checks and service.
		The following components were declared obsolete, pre-test: Interface connector box P/N 1132570-19, S/N 001 TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N 265382-19, S/N's 476, 478 Fuel Discharge lines P/N 256866-10, S/N's 054, 131 Lube Oil Cooler P/N 1130728-3, S/N 116 (TPA S/N 008, S/A-1) Turbine 2nd Nozz P/N 260825, S/N 685
		Combustion Chamber P/N 1133311-19, S/N 092 declared Experimental Pre-test.
10 July 68 1537 Hrs.	211	Conducted Peripheral Balance Adjustment test with High Thrust and Low MR. Duration 20.786; classification: Exclusion Prior.
		Hot firing Motion Picture Roll Film Nos. 8-857, 8-858, 8-859.
		Records indicate Lube Oil Filter performance within limits.
		TCA inspection revealed Teflon seal protruding internally at CC/Inj flange.
		Completed normal postfire checks and service.
		Replaced CC/Inj Raco Seals on both subassemblies.
		Loaded propellants into run tanks and conditioned to: Fuel 87°F, Oxidizer 90°F
		Performed Engine Balance change as follows: S/A-2 ODO was 3.40 is 3.55
		Installed Martin Co. Fuel Pogo Accumulators S/N's 101 and 130, on S/A-1 and S/A-2 respectively. Still photo Request No. 25541.

DATE	RUN NO.	REMARKS
		Completed all test stand and engine pre-fire checks and service. The following components were declared obsolete, pre-test: Interface connector box P/N 1132570-19, S/N 001 TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N 265382-19, S/N's 476, 478 Fuel Discharge lines P/N 256866-10, S/N's 054, 131 Lube Oil Cooler P/N 1130728-3, S/N 116 (TPA S/N 008, S/A-1) Turbine 2nd Nozzle P/N 260825, S/N 685 Combustion Chamber P/N 1133311-19, S/N 092 declared Experimental pre-test.
12 July 68 1800 Hrs.	212	Conducted Peripheral Test with Fuel Pogo Accumulators. Duration 201.100 seconds; classification: Success. Piggy-back fuel Pogo Test 3051-D21-1H-001 Hot firing motion picture roll film Nos. 8-0872, 8-0873, 8-0874. Records indicate Lube Oil Filter performance within limits. 1-PGfTA indicated zero pressure during test. Completed normal postfire checks and service. Subassembly-1 Turbine Seal leakage is 1100 cc/minute. Removed Superheaters and performed Turco Bath cleaning. Replaced both Sub-assembly Injector/Combustion chamber Raco seals.
15 July 68		Performed Turbine 2nd Rotor and Bolt dimensional inspection. Removed Fuel Pogo Accumulators and installed standard suction Bellows.

DATE	RUN NO.	REMARKS
		Completed Engine Balance change as follows: S/A-1 ODO was 3.70 is NONE FDO was NONE is 3.280 OBTV was .0278 is .0253 FBTV was .406 is .363 S/A-2 ODO was 3.55 is 3.70 FDO was NONE is NONE OBTV was .0299 is .0268 FBTV was .426 is .383
		Material Review Board disposition on IR against SA-1 excessive Turbine Seal was to accept "As-Is" for next test.
		Loaded propellants and conditioned to 63°F
		Removed and replaced 2-TB-6 which was erratic on Test -212.
		Completed all test stand and engine prefire checks and service.
		The following components were declared obsolete, pre-test: Interface connector box P/N 1132570-19, S/N 001 TPA P/N 1131352, S/N 006 Oxid Discharge lines P/N 265382-19, S/N's 476, 478 Fuel Discharge lines P/N 256866-10, S/N's 054, 131 Lube oil cooler P/N 1130728-3, S/N 116 (TPA S/N 008, S/A-1) Turbine 2nd Nozzle P/N 260825, S/N 685
		Combustion Chamber P/N 1133311-19, S/N 092 declared Experimental Pre-test.
16 July 68 1507 Hrs.	213	Conducted Peripheral Adjustment Test with Low Thrust and High Mixture Ratio. Duration 20.773 seconds; classification: Exclusion-Prior.
		Hot Firing Motion Picture Roll Film Nos. 8-0878, 8-0879 and 8-0880.
		Records indicate Lube Oil Filter performance within limits.

DATE	RUN NO.	REMARKS
		Inspection and records showed 2-TB-6 not bottomed against bearing.
17 July 68		Removed both Sub-assembly Turbine Kits and returned to Precision Assembly for inspection and further disposition.
		Replaced Injector to Combustion Chamber Raco Seals on both Sub-assemblies.
18 July 68		Received both sub-assembly Turbine Kits from Precision Assembly and completed installation. Reinstalled Superheaters.
		Installed Martin Co. ten (10) square inch, Moog Gimbal Actuators S/N 155, 156, 158, 157.
		Performed Engine Balance change as follows: S/A-1 FDO was 3.280 is 3.00 S/A-2 ODO was 3.700 is NONE FBTV was .383 is .3917
		Installed 12:1 Ablative Skirt S/N 003 on SA-1 and S/N 005 on SA-2.
		Modified 15:1 Martin Co. Refrasil Insulation Panels to fit 12:1 Ablative Skirts. Installed Modified Refrasil Insulation Panels on Engine.
		Conditioned propellants to $87^{\circ}F$.
		Completed all Test Stand and Engine pre-fire checks.
		The following components were declared obsolete, pre-test: Oxidizer Discharge Lines P/N 265382-19, S/N's 476, 478 Fuel Discharge Lines P/N 256866-19, S/N's 054, 131 Interface Connector Box P/N 1132570-19, S/N001 TPA P/N 1131352, S/N 006 Turbine 2nd Nozzle P/N 260825, S/N 685 Lube Oil Cooler P/N 1130728-3, S/N 116 (TPA S/N 008, SA-1)

DATE	RUN NO.	REMARKS
		The following components were declared Experimental, pre-test: Turbine 1st Rotor P/N 1154300-5, S/N 006(SA-1) Combustion Chamber P/N 1133311-19, S/N 092 (SA-2)
		The following components were declared Overage on Time-Cycles, pre-test: Fuel Elbows P/N 255662-29; S/N's 730 and 731.
22 July 68 1540 Hrs.	214	Conducted Peripheral Evaluation Test with Low Thrust and High Mixture Ratio. Gimbal Actuators were held at Null position. Duration 201.109 seconds; classification: Success.
		Piggy-back 12:1 Ablative Skirts and modified Refrasil insulation Test 3269-DO2-1A-001. Piggy-back 10^2 inch Martin Co. Gimbal Actuators Test 3051-DO3-1A-001.
		Hot Firing Motion Picture Roll Film Nos. 8-0910 through 8-0914, inclusive.
		Records indicate Lube Oil Filter performance within limits.
		Removed Modified Martin Co. Refrasil Insulation panels. No damage to panels.
		Ablative Skirts sustained some burn and charr damage on the outer linings on both sub-assemblies. Removed Ablative Skirts S/N's 003 and 005, and shipped to Building 2004, Plastics Shop.
		Removed both sub-assembly Superheaters and performed Turco bath cleaning.
24 July 68		Completed all postfire checks and service. Removed expended Solid Start Cartridges. Removed Martin Co. ten square-inch Gimbal Actuators and installed shipping struts. Removed Engine from Test Stand and forwarded to Manufacturing Division via D-Area for

DATE	RUN NO.	REMARKS
		decontamination. Engine was returned to Manufacturing Division for further inspection, disposition and rework.
19 August 68 2330 Hrs.		Received Engine S/N DEMO-14
20 Aug 68		Completed Receiving Inspection and installed Engine on Test Stand G-2
		Installed Thrust Standard Cells and completed Thrust calibrations.
		Installed Fuel Pogo Accumulators and Fuel Pre-valves
		Installed Low Delta Pressure GGfCKV on SA-1 Gas Generator.
		Installed Lube Oil and Lube Oil Filters on both TPA's.
		Performed the following Engine balance change: SA-1 FDO was 3.00 is NONE FBTV was NONE is .406 OBTV was .0253 is .0278 OPV was .0837 is .1040 OPBO was .320 is BLANK SA-2 FBTV was NONE is .435 OBTV was .0268 is .0300 OPBO was .320 is BLANK
		Loaded and conditioned propellants to 36°F.
		Installed test stand instrumentation and required impulse tubing. Connected purge and drain lines. Connected Fuel and Oxidizer Autogenous lines to test stand overboard lines.
		Completed test stand and Engine Sequence-Functional and TCPS Functional.
		Installed AS1149-16 orifice with .618" inside diameter at inlet to Sub-assembly 2 Gas Generator Fuel Check

DATE	RUN NO.	REMARKS
		Valve (GGFCKV), per Test Request Supplement #70.
		Installed Ablative Skirts S/N 032 on SA-1 and S/N 033 on SA-2.
		Installed Martin Co. Refrasil Insulation on both Sub-assemblies.
		Completed all test stand and Engine pre-fire checks and service.
		The following components were declared obsolete, pre-test: Oxid Discharge lines, P/N 265382-19, S/N's 476, 478 Fuel Discharge lines, P/N 256866-19, S/N's 054, 131 Interface Connector Box, P/N 1132570-19, S/N 001 Turbo Pump Assembly, P/N 1131352, S/N 006(SA-2) Turbine 2nd Nozzle, P/N 260825, S/N 685 Lube Oil Cooler, P/N 1130728, S/N 116 (SA-1)
		The following components were declared Experimental pre-test: Turbo Pump Assembly, P/N 1131352, S/N 006(SA-2) Combustion Chamber, P/N 1133311-19, S/N 092 Turbine 1st Rotor, P/N 1154300-5, S/N 006 (SA-1) Gas Generator Fuel Check Valve(SA-1) Not Serialized
		The following components were declared Overage On Time, pre-test: Fuel Elbows, P/N 255662-29, S/N's 730, 731.
27 Aug 68	215	Conducted Peripheral Evaluation Test for a duration of 200.591 seconds; classification: Success. No anomalies noted. Piggy-back Fuel Pogo Accumulators Test 3051-D21-1H-004.
		Hot Firing Motion Picture Roll Film Nos. 8-1234, 8-1235, 8-1236, 8-1237, 8-1238.
		Removed Ablative Skirts and shipped to Building 2002.

DATE	RUN NO.	REMARKS
		Removed Superheaters and performed Turco Bath cleaning. Completed Post-fire leak checks per TRS #72. Records indicate Lube Oil filters performance within limits. Removed Engine S/N DEMO-14 from test stand and shipped to Manufacturing Division, via D-4 for decontamination.

TEST SERIES: 3051-D07-1A-3XX

DATE	RUN NO.	REMARKS
22 May 68 2330 Hrs.		Received T-IIIM Demo Engine LR87-AJ-11, S/N 15
23 May 68		Performed Receiving-Inspection and installed Engine in test stand G-2. Installed Lube Oil Pumps in both Sub-assembly TPA's. Serviced TPA's with Lube Oil.
		Installed test stand instrumentation and required impulse tubing. Connected purge and drain lines. Connected Fuel and Oxidizer Autogenous lines to test stand overboard lines.
		Completed test stand and Engine Sequence-Functional and Engine TCPS functional.
		Performed Engine balance change as follows: SA-1 FBTV was Dummy is .3815 SA-2 FBTV was Dummy is .4060
		Conducted N2 Start Calibration Flow Check.
		Loaded Propellants and conditioned to 60°F.
		Completed test stand propellant line flush and contaminat check. Check good.
		During installation of Special Spring-loaded TB-5 thermocouples on both sub-assemblies, it was noted that the thermocouple bottomed against the spring-housing prior to touching the bearing. An Inspection Report (IR) was initiated and dispositioned to delete TB-5's and plug ports.
3 June 68		Completed pre-fire leak checks and all test stand and Engine pre-fire checks and service.
3 June 68 2300 Hrs.	301	Conducted Balance Adjustment Test for a duration of 20.687 seconds; classification: Exclusion Prior. No anomalies noted during test or post-fire visual inspection.
		Hot Firing Motion Picture Roll Film Nos. 8-0706, 8-0707, 8-0708.

DATE	RUN NO.	REMARKS
		Completed normal post-fire checks and service.
		Lube Oil Filter Cartridge performance within limits.
		Removed and replaced Injector to Combustion Chamber Raco Seals on both sub-assemblies by the long-bolt method.
		Re-worked TB-5 ports in Gearbox on both subassemblies by tapping and installed spring-loaded TB-5 thermocouples.
		Performed Engine Balance change as follows: SA-1 FDO was 3.28 is NONE SA-2 ODO was 3.87 is 3.620 OBTV was .0285 is .0299 FBTV was .4060 is .4260
5 June 68		Loaded propellants and conditioned fuel to 61°F and oxidizer to 60°F.
		The following components were declared obsolete, pre-test: Turbine 2nd nozzle P/N 260825-11, S/N's 662, 333 Lube oil coolers P/N 1130728-8, S/N's 164, 165
		The following components were declared Experimental pre-test: Turbine 1st rotors P/N 1154950-1, S/N's 001, 759 TCA Dome P/N 1155243-1, S/N's 004, 002
		Installed solid start cartridges and igniters.
6 June 68 1542 Hrs.	302	Conducted performance evaluation test for a duration of 201.133 seconds and classified Success. '2-NT instrumentation signal ceased at approximately FS-1 +95 seconds. No other anomalies noted.
		Hot Firing Motion Picture Roll Film Nos. 8-0718, 8-0719 and 8-0720.
		Instrumentation circuit checks indicate sub-assembly 2 turbine speed probe electrically open. Removed and

DATE	RUN NO.	REMARKS
		replaced 2-NT probe.
		Removed Superheaters from both sub-assemblies and performed Turco Bath cleaning.
		Completed normal post-fire checks and service.
		Removed and replaced injector to combustion chamber raco seals on both subassemblies, by the long bolt method. TCA inspection revealed small pieces of Teflon protruding from Injector orifices on sub-assembly-1.
		SA-1 TCA was removed, including Dome, injector and combustion chamber and forwarded to Final Assembly, Building 2002, for further inspection and disposition.
		Performed Turbine 2nd rotor and bolt dimensional check on both sub-assemblies.
		Checked fuel and oxidizer bootstrap screens and pressure-sequencing valve inlet screens on both sub-assemblies. Checks good.
13 June 68		Received SA-1 TCA from Final Assembly and installed on Engine.
		Re-installed superheaters.
		Loaded and conditioned propellants to approximately 60°F.
		Completed test stand and Engine Sequence-Functional, and all pre-fire checks.
14 June 68		Instrumentation Early-Calibration revealed 1-TCi electrically open. Inspection of the thermocouple, upon removal from the SA-1 fuel inlet elbow, showed the thermocouple portion parted, or separated from the base portion at the AN B-nut, and separated portion remaining inside the engine.

DATE	RUN NO.	REMARKS
		Removed Downstream Fuel Inlet Elbow and utilizing Nitrogen purge through a flexible hose, blew the tip of the failed thermocouple around and out of the combustion chamber fuel torus.
		Re-assembled SA-1 fuel inlet elbow and re-leak-checked.
		Installed solid start cartridges and igniters. Completed all pre-fire checks and service.
		The following components were declared obsolete, pre-test: Turbine 2nd nozzles P/N 260825-11, S/N's 662, 333 Lube oil coolers P/N 1130728-8, S/N's 164, 165
		The following components were declared Experimental, pre-test: Turbine 1st rotors P/N 1154950-1, S/N's 001, 759 TCA domes P/N 1155243-1, S/N's 004, 002
14 June 68 2256 Hrs.	303	Conducted Performance Evaluation Test for a duration of 200.446 seconds and classified Success. No abnormalities noted during test.
		Hot Firing Motion Picture Roll Film Nos. 8-073, 8-074, 8-075.
		Completed all normal post-fire checks and service.
		TCA inspection revealed the following: SA-1 Injector Baffle #1 had 5 orifice holes plugged with a foreign material. SA-2 Injector Baffle #2 had small strip of foreign material visible through the orifice holes. SA-2 Injector Baffle #6 had small foreign particles in orifice holes.
		The above listed foreign material appeared to be small chips of Teflon or similar substance. Material Review Board disposition on IR to accept AS-is, and continue testing.

DATE	RUN NO.	REMARKS
		Removed and cleaned both Superheaters in Turco bath.
17 June 68		Completed Turbine 2nd Rotor and Bolt dimensional checks.
		Removed and inspected OBTV and FBTV screens on both sub-assemblies. Removed and inspected OPV Screen and TCVPSV screens on both sub-assemblies All screen checks good. Replaced screens.
		Removed and replaced injector to combustion chamber Raco Seals on both sub-assemblies, utilizing Raco Seals P/N 701771 and 701773.
		Replaced Superheaters on both sub-assemblies.
		Loaded and conditioned propellants to fuel 61°F and oxid 63°F.
		Replaced 2-PC-6F helium-cooled Kistler due to leak.
		Installed solid start cartridges and igniters.
		Completed all test stand and engine pre-fire checks.
		The following components were declared obsolete, pre-test: Turbine 2nd nozzles P/N 260825-11, S/N's 662, 333 Lube oil coolers P/N 1130728-8, S/N's 164, 165
		The following components were declared Experimental, pre-test: Turbine 1st rotors P/N 1154950-1, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002
18 June 68 1806 Hrs.	304	Conducted Performance Evaluation Test for a duration of 200.843 seconds and classified Success. No abnormalities noted.
		Hot firing Motion Picture Roll Film Nos. 8-0751, 8-0752, 8-0753.

DATE	RUN NO.	REMARKS
		TCA inspection revealed smaller quantity of foreign material in SA-1 injector orifices and none in SA-2.
		Postfire leak checks revealed SA-2 fuel bootstrap line leaking through braid. Removed FBTL S/N 542 and installed FBTL S/N 536.
		Completed turbine kit inspection on both sub-assemblies. Replaced SA-1 turbine 2nd nozzle S/N 662 with S/N 659. Replaced SA-2 Turbine 2nd Nozzle S/N 333 with S/N 666.
		Completed normal post-fire checks and service.
		Removed and replaced Injector to Combustion Chamber Raco seals on both sub-assemblies.
		Removed Superheaters from both sub-assemblies and performed Turco Bath cleaning.
		Re-installed Superheaters.
		Loaded propellants into run tanks and conditioned to 60°F.
24 June 68		Installed Gimbal Actuators and completed Gimbal pre-fire calibration.
		Completed pre-fire checks.
		Installed Ablative Skirts S/N's 035 and 038 on SA-1 and SA-2 respectively.
		Installed Martin Co. Refrasil Insulation on both sub-assemblies.
		Installed solid start cartridges and igniters.
		The following components were declared obsolete, pre-test: Turbine 2nd nozzles P/N 260825-11, S/N's 662, 333 Lube oil coolers P/N 1130728-8, S/N's 164, 165

DATE	RUN NO.	REMARKS
		The following components were declared Experimental, pre-test: Turbine 1st Rotors P/N 1154950-1, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002
24 June 68 2120 Hrs.	305	Conducted Performance Evaluation Test for a duration of 200.650 seconds with no abnormalities noted. Gimballing performed at approximately FS-1 plus 5 seconds, and again at FS-1 plus 165 seconds.
		Hot firing Motion Picture Roll Film Nos. 8-0778, 8-0779, 8-0780, 8-0781, 8-0782.
		Post-fire inspection revealed some un-lacing on both refrasil insulation under the TPA's.
		Completed refrasil insulation removal.
		During ablative skirt removal, erratic action of gimbal-hydraulic system caused outer lineing and honeycomb minor damage to both ablative skirts in areas approximately 3-inch x 8-inch.
		Removed Superheaters from both sub-assemblies and performed Turco Bath cleaning.
		Performed normal post-fire checks and service.
27 June 68		Removed SA-2 TPA and forwarded to M.D. via D-4 for decontamination.
		Removed both TCA's for tube leakage repair on CC S/N 477 and 478, and injector baffle base weld crack repair on Injectors S/N 699 and S/N 698.
		Performed turbine kit removal and replacement on SA-1 for static seal leakage repair.
		Removed, inspected and replaced SA-1 TPA lube oil pump for snap ring inspection.
		Installed Superheaters.

DATE	RUN NO.	REMARKS
		Removed, inspected and re-installed SA-1 gas generator.
24 July 68		Received both TCA's repaired and assembled from Manufacturing Division and installed them on engine. Installed SA-2 TPA S/N 011 on Engine. Performed Engine balance change as follows: 1-OPBO was .320 is BLANK 2-OPBO was .320 is BLANK OPV was .0833 is .0848 Completed all normal pre-fire checks and service. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles P/N 260825-11, S/N's 659, 666 Lube Oil Coolers, P/N 1130728-8, S/N's 164, 165 The following components were declared Experimental pre-test: Turbine 1st Rotors P/N 1154950-11, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002 Installed solid start cartridges and igniters.
26 July 68 1250 Hrs.	306	Conducted Performance Evaluation Test for a duration of 200.846 seconds with no anomalies. Gimbal actuators were held in Null position. Hot Firing Motion Picture Roll Film Nos. 8-0931, 8-0932, 8-0933. Completed normal post-fire checks and service. Removed Superheaters and performed Turco Bath cleaning. Removed expended solid start cartridges. Completed 2nd rotor and rotor-bolt inspection on both sub-assemblies. Replaced both GGA/TM gaskets, FPBO gasket, and

DATE	RUN NO.	REMARKS
		SA-1 Hot Gas Inlet Line Blank Flange gasket to correct static seal leakage.
		Re-installed Superheaters.
		Completed Test Stand and Engine pre-fire checks and service.
		Installed Ablative Skirts S/N 14 and 21 on SA-1 and SA-2 respectively.
		Installed flight-instrumentation for exit closures. Installed exit closure ordnance. Performed electrical functional of exit closure squib circuit.
		Installed special N_2 system for oxidizer lead pressure simulation with remote control regulation.
		Installed Martin Co. Refrasil Insulation.
		Installed Exit Closures S/N's 006 and 005 on SA-1 and 2 respectively.
		At this time a Design-Change Proposal was initiated to install Refrasil Insulation Exit Flange on the outside of the Exit Closure Flange instead of on the inside
		A nylon net was stretched below the Engine to catch Exit Closures at separation.
1 Aug 68 1544 Hrs.		Conducted Exit Closure Expulsion Test: 3051-DO8-1V-001; classification: Success. Took still photos of tensile strips and CC Exit Flanges. Took still photos of Exit Closures in net.
		Retrieved Exit Closures and retracted nylon net.
		Sawed through attaching ring on both sides of Lower Ordnance Manifold on SA-2 for Attaching-Bracket reliability check during hot firing.

DATE	RUN NO.	REMARKS
		The following components were declared obsolete, pre-test: Turbine 2nd Nozzles P/N 260825-11, S/N's 659, 666 Lube Oil Coolers, P/N 1130728-8, S/N's 164, 165 The following components were declared Experimental, pre-test: Turbine 1st Rotors P/N 1154950-11, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002
1 Aug 68 1846 Hrs.	307	Conducted Minimum NPSH Test for a duration of 200.582 seconds, with Gimballing; classification: Success. Hot Firing Motion Picture Roll Film Nos. 8-0966, 8-0967, 8-0968, 8-0969, 8-0970, 8-0971. Cold-Test Exit Closure Motion Picture Roll Film Nos. 8-0972, 8-0973. Completed all normal post-fire checks and service. Removed Superheaters and performed Turco Bath cleaning. Fabricated and installed special fitting for SA-1 TTMB. Performed following Engine Balance change: SA-1 ODO was NONE is 3.70 OBTV was .0267 is .0272 FBTV was .3815 is .3900 OPV was .0848 is .1072 SA-2 ODO was 3.62 is 3.55 FBTV was .4260 is .4280 Installed Martin Co. Fuel Pre-Valves with ruptured diaphrams. Re-installed Superheaters. Removed Gimbal Actuators and installed Strain-Gaged Solid Struts.

DATE	RUN NO.	REMARKS
		Both sub-assembly oxidizer pump seals leaking in excess of 18,000 cc/min. MRB Disposition to accept "as-is."
		Pre-fire photos of fuel pre-valves on Job No. 28703.
		The following components were declared obsolete, pre-test: Turbine 2nd Nozzles P/N 260825-11, S/N's 659, 666 Lube Oil Coolers, P/N 1130728-8, S/N's 164, 165
		The following components were declared Experimental, pre-test: Turbine 1st Rotors P/N 1154950-11, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002
		Loaded and conditioned propellants.
14 Aug 68 0230 Hrs.	308	Conducted Balance Adjustment Test for a duration of 20.994 seconds; classification: Exclusion Prior.
		Hot Firing Motion Picture Roll Film Nos. 8-1081, 8-1082, 8-1083, 8-1084, 8-1085, 8-1086.
		Completed normal post-fire checks and service. Both sub-assembly oxidizer pump seals leaking in excess 18,000 cc/min.
		Installed Martin Co. Fuel Pogo Accumulators S/N 101, and 130 and Martin Co. Fuel Pre-valves, S/N's 1852, and 2000.
		Loaded and conditioned propellants to 85° to 90°F.
		Completed all Test Stand and Engine pre-fire checks and service.
		Installed solid start cartridges and igniters.
		The following components were declared obsolete, pre-test:

DATE	RUN NO.	REMARKS
		Turbine 2nd Nozzles, P/N 260825-11, S/N's 659,666 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165 The following components were declared Experimental pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002.
15 Aug 68 1603 Hrs.	309	Conducted Peripheral Test for a duration of ?.568 seconds; classification: Failure. SA-1 failed to run, with solid start cartridge burn only. Piggy-back Fuel Pogo Accumulators Test 3051-D21-1H-002. Post-fire functional of thrust chamber valves revealed SA-1 TCVPSV-OR was stuck in the energized position. Completed Lube oil service and hot gas cooler cleaning. Removed Superheaters and performed Turco Bath cleaning. Removed SA-1 PSV S/N 640 and installed PSV S/N 641. Re-installed Superheaters. SATRS #67 deleted post-fire leak checks, 2nd nozzle and bolt inspection, pre-fire TCA leak checks and injector/CC Raco Seal replacement. Completed all pre-fire checks and service. Conditioned propellants to 85° to 90°F. Installed solid start cartridges and igniters. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 659, 666 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165

DATE	RUN NO.	REMARKS
		The following components were declared Experimental pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 001, 759 TCA Domes P/N 1155243-1, S/N's 004, 002
16 Aug 68 1530 Hrs.	310	Conducted Peripheral Test with +2% Thrust and -7% Mixture Ratio; duration: 200.492 seconds; classification: Success.
	•	Piggy-back Fuel Pogo Accumulators Test 3051-D21-1H-003.
		Hot Firing Motion Picture Roll Film Nos. 8-1119, 8-1120, 8-1121, 8-1122, 8-1123, 8-1124.
		Completed all normal post-fire checks and service. Removed Superheaters and performed Turco Bath cleaning.
		Both sub-assembly oxidizer pump seals leaking in excess of 18,000 cc/minute.
20 Aug 68		Removed Engine from Test stand and forwarded to Manufacturing Division via D-4 for decontamination.
12 Sept 68		Received Engine DEMO-15 from Manufacturing Division at 2300 Hours. Performed receiving-inspection and installed Engine in Test Stand G-2.
		Performed N_2 Start Calibration Flow check. Installed Strain-Patched Gimbal Struts.
		Installed SA-1 and SA-2 Oxidizer Flush Mounted Micro transducer bosses 22 inches upstream from oxidizer pump inlets; 1-POS-22-F(M), and 2-POS-22-F(M).
		Loaded and conditioned propellants to $60^{\circ} \pm 5^{\circ}F$.
		Installed Lube Oil Cartridge Filters S/N's 092 and 093 in SA-1 and SA-2 respectively, and serviced TPA's with lube oil.

DATE	RUN NO.	REMARKS
		Performed test stand and Engine Sequence-Functional and Engine TCPS Functional. Performed Engine Balance Change as follows: SA-1 ODO was 3.700 is NONE FDO was NONE is 3.100 OBTV was .0272 is .0253 FBTV was .3900 is .355 OPV was .1072 is .1034 SA-2 ODO was 3.55 is NONE FDO was NONE is 3.400 OBTV was .0299 is .0272 FBTV was .4280 is .383 Initial pre-fire Still Photo Job No. 32233. Completed Test Stand and Engine pre-fire checks. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165 The following components were declared Experimental, pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
17 Sept 68 1515 Hrs.	311	Conducted Balance Adjustment Test for a duration of 21.358 seconds. Classification: Exclusion-Prior. No anomalies noted. Hot Firing Motion Picture Roll Film Nos. 8-1394, 8-1395, 8-1396. Static head pressure water leak check of combustion chambers revealed the following:

DATE	RUN NO.	REMARKS
		SA-1: Tubes 116 through 119 1-1/4 cc/min SA-2: Tubes 13 through 17, 30-31-32, 40 through 44, 58 through 68, and Tube 25 10 cc/min. All tube leakage is at Tube-weld to Inlet Flange. Inspection and data showed lube oil performance within limits. Completed all normal post-fire checks and service. Installed in-flight transducers, 1-PLD, and 1-PGGB. Installed 1-POS-22 and 2-POS-22, 500 PSI Taber transducers. Removed and replaced Injector-to-Combustion Chamber Raco Seals. Loaded and conditioned propellants to 90°F. No Engine Balance change required for next test. Performed solid start cartridge simulation functional. Installed Martin Co. Fuel Pogo Accumulators S/N's 001, and 002 on SA-1 and SA-2 respectively. Photo Job No. 32727. Installed Martin Co. Fuel Pre-valves S/N's 1852, and 2000 on SA-1 and SA-2 respectively. Completed Test Stand and Engine pre-fire checks. Installed solid start cartridges and igniters. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165

DATE	RUN NO.	REMARKS
		The following components were declared Experimental, pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
19 Sept 68 1530 Hrs.	312	Conducted Peripheral Test for a duration of 201.224 seconds with Engine balanced for -3% Thrust and +6% Mixture Ratio. No abnormalities noted. Lost 2-TTi-1 almost immediately after FS_1, but 2-TTi-2 valid. Piggy-back fuel Pogo Accumulators Test 3051-D21-1H-005 Hot Firing Motion Picture Roll Film Nos. 8-1420, 8-1421, 8-1422. Static head pressure water leak check of combustion chambers revealed the following: Post-Test -311(Recap) / Post-Test -312 SA-1 1-1/4 cc/min / 6 cc/min SA-2 10 cc/min / 30 cc/min Tube Nos. same as -311 Completed normal post-fire checks and service. Removed Superheaters and performed Turco Bath cleaning. Removed Martin Co. Fuel Pogo Accumulators for compliance check. Installed long Engine Suction Bellows. Performed 2nd Rotor and Turbine Bolt dimensional check. Re-installed Superheaters. Completed Injector-to-Combustion Chamber Raco Seal removal and replacement.

DATE	RUN NO.	REMARKS
		Replaced SA-2 N_2 Start Valve, and performed N_2 Start Calibration Flow check. Performed Engine Balance Change as follows: SA-1 ODO was NONE is 3.400 FDO was 3.100 is NONE FBTV was .355 is .359 OPV was .1034 is .1113 SA-2 ODO was NONE is 3.300 FDO was 3.400 is NONE OBTV was .0272 is .0279 FBTV was .383 is .397 Completed all test stand and Engine pre-fire checks. Pre-test Photo Job No. 33176. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165 The following components were declared Experimental, pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
28 Sept 68 0111 Hrs.	313	Conducted Adjustment, Baseline Pogo Test for a duration of 20.860 seconds, with Engine balanced for -4% Thrust and -4.3% Mixture Ratio. Noted slight flame flicker post FS_2 in vicinity of SA-1 TPA; utilized approximately 2 seconds of deluge. Hot Firing Motion Picture Roll Film Nos. 8-1472, 8-1473, 8-1474. Static head pressure water leak check of Combustion Chambers revealed the following:

DATE	RUN NO.	REMARKS
		Post -311(Recap) Post-312(Recap) Post -313 SA-1 1-1/4 cc/min 6 cc/min 20 cc/min SA-2 10 cc/min 30 cc/min 125 cc/min Inspection and data indicates lube oil performance within limits. Completed normal post-fire checks and service. Removed SA-2 Combustion Chamber S/N 022 for tube leakage repair. Repaired specified tubes in CC S/N 022 and re-installed on Engine. Static water leakage rate is now 30 cc/min. Completed Injector-to-Combustion Chamber Raco Seal removal and replacement. Installed Martin Co. Fuel Pogo Accumulators S/N's 001 and 002 on SA-1 and SA-2 respectively, with Martin Co. Fuel Pre-valves S/N's 1852 and 2000 already installed. Still Photo Job No. 33853. Performed solid start cartridge simulation functional. Completed all test stand and Engine pre-fire checks. Installed solid start cartridges and igniters. Conditioned propellants to 38°F. Performed Engine Balance change as follows: SA-1 OPV was .1113 is .0848 The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165

DATE	RUN NO.	REMARKS
		The following components were declared Experimental, pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
1 Oct 68 1455 Hrs.	314	Conducted Peripheral Test for a duration of 201.012 seconds, with the Engine balanced for -4% Thrust and -4.3% Mixture Ratio. Fuel Suction Pressure Excursion was performed on this Test per Test Request Supplement #74. No abnormalities noted. Piggy-back Fuel Pogo Accumulators Test 3051-D21-1H-006. Hot Firing Motion Picture Roll Film Nos. 8-1498, 8-1499, 8-1500. Static head pressure water leak check of Combustion Chambers revealed the following: Post -313(Recap) / Post -314 SA-1 20 cc/min / 20 cc/min SA-2 30 cc/min (after repair) / 80 cc/min Removed and replaced SA-1 N_2 start valve. Performed N_2 start calibration flow check. Removed Superheaters and performed Turco Bath cleaning. Performed Turbine 2nd Rotor and Turbine Rotor-Bolt dimensional checks. Re-installed Superheaters. Removed Martin Co. Fuel Pogo Accumulators and performed compliance check. Loaded and conditioned propellants to $60^{o}F$. Removed and replaced Injector-to-Combustion Chamber Raco Seals. Machined and installed Cavitation-Suppression Orifice

DATE	RUN NO.	REMARKS
		of .500 inches I.D. in Fuel Bootstrap line immediately upstream of GGFCKV, on SA-2. Performed Engine Balance change as follows: SA-1 ODO was 3.400 is NONE FDO was NONE is 3.100 OBTV was .0253 is .0268 FBTV was .359 is .383 OPV was .0848 is .1034 SA-2 ODO was 3.400 is NONE FDO was NONE is 3.400 OBTV was .0279 is .0291 FBTV was .397 is .435 Completed all test stand and Engine pre-fire checks. The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165 The following components were declared Experimental, pre-test: Turbine 1st Rotors, P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
3 Oct 68 1950 Hrs.	315	Conducted Balance Adjustment Test for a duration of 21.115 seconds with the Engine balanced for +3% Thrust and +2% Mixture Ratio. No abnormalities, and test classified Exclusion-Prior. Hot Firing Motion Picture Roll Film Nos. 8-1510, 8-1511, 8-1512. During post-fire leak checks, SA-2 GGOCKV leaked in excess of 12,000 cc/min. 2-GGOCKV, S/N 870 was removed and sent to the Controls Lab. No discrepancy was noted during checkout at the Controls Lab. GGOCKV S/N 870 was returned and re-installed on the Engine.

DATE	RUN NO.	REMARKS
		Static head pressure water leak check of Combustion Chambers revealed the following: Post -314(Recap) — Post -315 SA-1: 20 cc/min — 10 cc/min SA-2: 80 cc/min — 95 cc/min Post-fire leak checks at 50 psi revealed pinhole leakage in SA-2 Combustion Chamber, S/N 022, externally, immediately below wire-wrap. This leakage was repaired with Prema Braze 250 Alloy, with Combustion Chamber installed on Engine. Still Photo Job Nos. 35118 and 35334. Removed and replaced Injector-to-Combustion Chamber Raco Seals. Removed SA-1 FBTV, Kv .383; installed 1-FBTV, Kv .397. Completed all normal post-fire checks and service. Installed Martin Co. Fuel Pogo Accumulators. Completed pre-fire leak checks, Test Stand and Engine pre-fire checks. Loaded and conditioned propellants to 36°F. Weld-repaired cracks in upper corset attaching points. Installed Ablative Skirts S/N's 039 and 040 on SA-1 and SA-2 respectively. Installed CDF Cables and Manifolds for Exit Closures. Still Photo Job No. 35794. Installed Martin Co. Refrasil Insulation. Installed Exit Closures S/N's 007 and 008 on SA-1 and SA-2 respectively. Still Photo Job No. 35986.

DATE	RUN NO.	REMARKS
		Installed solid start cartridges and CDF Squibs.
		Calibrated PEC (GN_2 Pressure to simulate oxidizer lead for Exit Closure Expulsion Test).
17 Oct 68 1055 Hrs.		Performed Piggy-back Exit Closure Expulsion Test 3051-DO8-1V-002, with no anomalies. Retrieved Exit Closures. Still Photo Job No. 36006. Hot Test Motion Picture Roll Film Nos. 8-1601, 8-1602.
		Installed igniters for solid start cartridges.
		The following components were declared obsolete, pre-test: Turbine 2nd Nozzles, P/N 260825-11, S/N's 743, 746 Lube Oil Coolers, P/N 1130728-3, S/N's 164, 165
		The following components were declared Experimental, pre-test: Turbine 1st Rotors P/N 1154950-1, S/N's 783, 788 TCA Domes, P/N 1155243-1, S/N's 004, 002
17 Oct 68 1606 Hrs.	316	Conducted Peripheral Test for a duration of 200.957 seconds. Gimballing was performed at FS_1 + 5 seconds to FS_1 + 30 seconds, and again at FS_1 + 165 seconds to FS_1 + 190 seconds. Post FS_2 a small fire was noted in area of SA-1 Fuel Pump Seal Cavity drain and deluge was utilized. No other anomalies noted. Piggy-back Fuel Pogo Accumulators Test 3051-D21-1H-007.
		Hot Firing Motion Picture Roll Film Nos. 8-1590, 8-1591, 8-1592, 8-1593, 8-1594.
		Removed Refrasil Insulation and Ablative Skirts. Lockwire lacing missing from lower 15 capstans on SA-2 inboard seam. Approximately ten (10) exit flange bolt holes of Refrasil Insulation torn away from bolts, in area of SA-2 inboard seam. Some discoloration of Refrasil Insulation on external surfaces. Ablative Skirts appear to be in excellent condition.

DATE	RUN NO.	REMARKS
		Serviced TPA Lube Oil Systems, and flushed PSV's and cleaned Fuel Autogenous Hot Gas Cooler. Static head pressure water leak check of Combustion Chambers revealed the following: Post -315(Recap) / Post -316 SA-1 10 cc/min / 11 cc/min SA-2 95 cc/min / 95 cc/min Removed Superheaters and performed Turco Bath cleaning. Deleted post-fire leak checks, Injector-to-Combustion Chamber Raco Seal Replacement, and Turbine Inspection per TRS #72. Completed all post-fire checks and service.
18 Oct 68 2330 Hrs..		Removed Engine S/N DEMO-15 from Test Stand G-2, and forwarded to Manufacturing Division via D-4 for decontamination.

TITAN III M DEMONSTRATION TESTING
YLR 87-11 SN DEMO-14

TURBO PUMP ASSEMBLY SERVICE

	TEST Nº	201		202		203		204		205
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1
LUBE OIL	TOTAL QUANTITY DRAINED, CC	7353	7368	8280	8240	8140	8000	7175	TPA REMOVED	7860
	SAMPLE REFERRAL Nº	04173	04175	04191	04192	04106	04105	04113	& RETURNED TO M.D.	04119
	MAX ΔPLF DURING TEST	1.11	.18	.69	.76	.68	.72	1.19	.80	1.22
	FILTER S/N	92	93	92	93	90	91	92	93	90
	BATCH Nº	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1
	TPA TORQUE (IN-LBS) BREAK AWAY	85	90	144	180	115	165	96	SEIZED	96
	TPA TORQUE (IN-LBS) RUN	80	120	108	144	80	160	84	SEIZED	108
	SOLID START CARTRIDGE S/N	NA	NA	4116	4156	859656	859660	4153	859613	NA
	IGNITER S/N	NA	NA	649	650	637	638	631	632	NA
	TEST DURATION	19.62		200.994		200.706		115.438		20.8

	TEST Nº	209		210		211		212		213
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1
LUBE OIL	TOTAL QUANTITY DRAINED, CC	6940	6860	8010	8060	8545	8235	8230	8095	8075
	SAMPLE REFERRAL Nº	04561	04569	04179	04178	04182	04183	03476	03477	04563
	MAX ΔPLF DURING TEST	1.68	1.38	1.52	8.00	1.17	1.1	1.06	1.07	1.2
	FILTER S/N	13	14	3	4	92	93	92	93	13
	BATCH Nº	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1	87LF1
	TPA TORQUE (IN-LBS) BREAK AWAY	252	132	108	96	108	120	100	100	96
	TPA TORQUE (IN-LBS) RUN	240	120	96	84	102	108	75	95	90
	SOLID START CARTRIDGE S/N	NA	NA	859661	859671	NA	NA	5407	5408	NA
	IGNITER S/N	NA	NA	725	726	NA	NA	729	730	NA
	TEST DURATION	20.586		200.407		20.786		201.100		20.7

AN III M DEMONSTRATION TESTING

YLR 87-11 SN DEMO-14

TEST SERIES: 3051-D07-XXX

PUMP ASSEMBLY SERVICE

	203		204		205		206		207		208	
2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
10	8140	8000	7175	TPA REMOVED & RETURNED TO M.D.	7860	7155	8090	8310	8108	8338	7400	7530
92	04106	04105	04113		04119	04120	03302	03301	04201	04202	04600	04599
6	.68	.72	1.19	.80	1.22	1.20	1.30	1.39	.85	4.39	1.67	1.11
3	90	91	92	93	90	91	92	93	90	91	92	93
FI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI
0	115	165	96	SEIZED	96	96	108	108	108	96	110	115
4	80	160	54	SEIZED	108	84	96	96	96	84	95	100
56	859656	859660	4153	859613	NA	NA	4106	4137	649	659	NA	NA
50	637	638	631	632	NA	NA	633	644	635	636	NA	NA
	200.706		115.438		20.88		201.040		200.722		21.235	

	211		212		213		214		215			
-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
60	8545	8235	8230	8095	8075	7875	7800	7800	7275	7165		
78	04182	04183	03476	03477	04563	04564	04164	04570	04453	04454		
0	1.17	1.1	1.06	1.07	1.2	1.15	1.0	1.2	1.2	.85		
	92	93	92	93	13	14	13	14	13	2		
FI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI	B7LFI		
6	108	120	100	100	96	120	108	204	100	170		
4	102	108	75	95	90	108	96	180	75	160		
571	NA	NA	5407	5408	NA	NA	4105	5334	2508	4142		
5	NA	NA	729	730	NA	NA	711	712	655	656		
	20.786		201.100		20.773		201.109		200.591			

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TITAN III M DEMONSTRATION TESTIN

YLR 87-11 SN DEMO-15

TURBO PUMP ASSEMBLY SERVICE

	TEST №	301		302		303		304		305	
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	S
LUBE OIL	TOTAL QUANTITY DRAINED, CC	7160	7165	6075	6065	7480	7090	8015	7900	8235	8
	SAMPLE REFERRAL №	04556	04557	04121	04130	04138	04139	04137	04122	04559	04
	MAX ΔPLF DURING TEST	1.07	1.14	1	1	1.63	1.4	1.01	1.11	1.77	
	FILTER S/N	92	93	92	93	3	4	93	92	3	
	BATCH №	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7
	TPA TORQUE (IN-LBS) BREAK AWAY	90	140	132	120	210	140	130	100	140	
	TPA TORQUE (IN-LBS) RUN	70	130	120	108	140	110	110	80	130	
	SOLID START CARTRIDGE S/N	NA	NA	4144	860648	4090	859653	4108	4150	5333	85
	IGNITER S/N	NA	NA	736	737	734	735	721	722	723	
	TEST DURATION	20.687		201.133		200.446		200.943		200.6	

	TEST №	309		310		311		312		313	
		SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	S
LUBE OIL	TOTAL QUANTITY DRAINED, CC	7400	7700	8560	8750	7850	7905	8250	7870	7635	7
	SAMPLE REFERRAL №	04595	04593	04587	04588	04501	04502	04535	04536	04519	04
	MAX ΔPLF DURING TEST	NA	1.97	.8	16.26	1.04	.86	8.56	1.28	1.86	1.
	FILTER S/N	2	3	2	8	92	93	92	93	4	
	BATCH №	B7LF1	B7LF1	B8LA1	B8LA1	B8LA1	B8LA1	B8LG1	B8LG1	B8LG1	B
	TPA TORQUE (IN-LBS) BREAK AWAY	110	105	120	100	105	200	80	105	100	2
	TPA TORQUE (IN-LBS) RUN	100	100	110	90	95	190	75	100	95	2
	SOLID START CARTRIDGE S/N	4133	4135	2561	4162	NA	NA	4161	859609	NA	
	IGNITER S/N	715	716	727	728	NA	NA	661	662	NA	
	TEST DURATION	2.562		200.492		21.358		201.224		20.86	

III M DEMONSTRATION TESTING

YLR 87-11 SN DEMO-15 TEST SERIES: 3051-D07-XXX

MP ASSEMBLY SERVICE

303		304		305		306		307		308	
SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
7480	7090	8015	7900	8235	8205	7305	7125	3540	7665	7790	7791
04138	04139	04137	04122	04557	04558	04572	04571	04573	04574	04591	04590
1.63	1.4	1.01	1.11	1.77	1.18	1.6	2.3	1.22	1.05	1.0	1.9
3	4	93	92	3	4	3	4	93	92	2	3
B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B7LF1	B8LA1	B8LA1
210	140	130	100	140	105	150	170	129.6	90	160	120
140	110	110	80	130	100	150	130	120	72	140	70
4090	859653	4108	4150	5333	859650	4147	5335	4124	4132	NA	NA
734	735	721	722	723	724	713	714	386	387	NA	NA
200.446		200.843		200.650		200.846		200.582		20.994	

311		312		313		314		315		316	
SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2	SA-1	SA-2
7850	7905	8250	7870	7635	7580	7435	7445	7620	7600	7800	7868
04501	04502	04535	04536	04519	04520	04494	04495	04490	04491	04479	04480
1.04	.86	8.56	1.28	1.86	1.90	1.08	1.98	5.28	2.15	18.41	1.64
92	93	92	93	4	13	4	13	8	14	8	14
B8LA1	B8LA1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1	B8LG1
105	200	80	105	100	220	100	110	195	135	100	180
95	190	75	100	95	200	95	105	95	125	90	170
NA	NA	4161	859609	NA	NA	5331	5332	NA	NA	5405	5415
NA	NA	661	662	NA	NA	658	659	NA	NA	2461	2467
21.358		201.224		20.860		201.012		21.115		200.957	

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APPENDIX D

Component Records

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Table I --Titan IIIM Stage I Engine Tim

Part No.	Name	Top Assembly Name	S/N	Test Date Dur. S/A	3051-D07-1A-201 12-20-67 19.657 (N_2) 1	2	3051-D07-1A-202 12-29-67 200.825 (S) 1	2	3051-D0 1-1 200.5 1
1129050-19	Frame Assy	Eng	D-14	SN Fired	605	-	605	-	605
256866-19	Fuel Disch Ln	Eng	D-14	SN Fired	054	131	054	131	054
265382-19	Ox Disch Ln	Eng	D-14	SN Fired	476	478	476	478	476
294252/ 255639-19	Fuel Suct Ln	Eng	D-14	SN Fired	695	647	695	647	695
294251	Ox Suct Ln	Eng	D-14	SN Fired	624	625	624	625	624
261285-39	Fluid Heater	Eng	D-14	SN Fired	378	376	378	376	378
284899-19	Hot Gas Cooler	Eng	D-14	SN Fired	-	753	-	753	-
709987-29	Gas Gen Assy	Eng	D-14	SN Fired	492	493	492	493	492
250375-79	Gas Gen Chamber	GGA	492 493	SN Fired	492	493	492	493	492
705574-39	GGFCKV	GGA	492 493	SN Fired	504	506	504	506	504
702642-59	GGOCKV	GGA	492 493	SN Fired	871	872	871	872	871
259387	FBTL	GGA	492 493	SN Fired	540	543	540	543	540
1131888-1	OBTL	GGA	492 493	SN Fired	1604	1605	1604	1605	1604
1131273-9	TCA	Eng	D-14	SN Fired	475	476	475	476	475
1130063-19	TCOV	TCA	475 476	SN Fired	606	604	606	604	606
1130064-9	TCFV	TCA	475 476	SN Fired	674	676	674	676	674
1131736	PSV	TCA	475 476	SN Fired	643	644	643	644	643
255662-29	Fuel Elbow (U/S)	TCA	475 476	SN Fired	730	731	730	731	730
285992-9	Fuel Elbow (A/S)	TCA	475 476	SN Fired	236	237	236	237	236
1131576-1	Ox Elbow	TCA	475 476	SN Fired	007	003	007	003	007
1129532-39	Gimbal Assy	TCA	475 476	SN Fired	003	002	003	002	003
1130174-79	Combustion Chamber	TCA	475 476	SN Fired	019	020	019	020	019
1129910-17	Dome Assy	TCA	275 476	SN Fired	523	522	523	522	523

ge I Engine Time-Cycle Log Engine S/N 14

-1A-202	3051-D07-1A-203		3051-D07-1A-204		3051-D07-1A-205		3051-D07-1A-206		3051-D07-1A-207	
-67	1-10-68		3-11-68		4-4-68		4-10-68		4-29-68	
5 (S)	200.585 (S)		115.438 (S)		20.851 (N_2)		200.925 (S)		200.599 (S)	
2	1	2	1	2	1	2	1	2	1	2
-	605	-	605	-	605	-	-	605	-	605
131	054	131	054	131	054	131	054	131	054	131
478	476	478	476	478	476	478	476	478	476	478
647	695	647	695	647	695	647	695	647	695	647
625	624	625	624	625	624	625	624	625	624	625
376	378	376	378	376	378	376	378	376	378	376
753	-	753	-	753	-	755[10]	-	755	-	755
493	492	493	492	493	492	493	492	493	492	493
493	492	493	492	493	492	493	492	493	492	493
506	504	506	504	506	504	506	504	506	504	506
872	871	872	871	872	871	872	871	872	871	872
543	540	543	540	543	540	543	540	543	540	543
1605	1604	1605	1604	1605	1604	1605	1604	1605	1604	1605
476	475	476	475	476	475	476	475	476	475	476
604	606	604	606	604	606	604	606	604	606	604
676	674	676	674	676	674	676	674	676	674	676
644	643	644	643	644	643	644	643	644	643	644
731	730	731	730	731	730	731	730	731	730	731
237	236	237	236	237	236	237	236	237	236	237
003	007	003	007	003	007	003	007	003	007	003
002	003	002	003	002	003	002	003	002	003	002
020	019	020	019	017	019	017	019	017	017[17]	019[17]
522	523	522	523	522	523	522	523	522	523	522

2

Table I --Titan IIIM Stage I Engine Ti

Part No.	Name	Top Assembly Name	Top Assembly S/N		Test Date Dur. S/N	3051-D07-1A-208 5-4-68 21.215 (N_2) 1	2	3051-D07-1A-209 7-1-68 20.575 (N_2) 1	2
1129050-19	Frame Assy	Eng		D-14	SN Fired	605	-	605	-
256866-19	Fuel Disch Ln	Eng		D-14	SN Fired	054	131	054	131
265382-19	Ox Disch Ln	Eng		D-14	SN Fired	476	478	476	478
294252/255639	Fuel Suct Ln	Eng		D-14	SN Fired	695	647	695	647
294251	Ox Suct Ln	Eng		D-14	SN Fired	624	625	625 (18)	624 (18)
261885-39	Fluid Heater	Eng		D-14	SN Fired	378	376	378	376
224899-19	Hot Gas Cooler	Eng		D-14	SN Fired	-	755	-	755
709987-19	Gas Gen Assy	Eng		D-14	SN Fired	492	493	492	493
250375-19	Gas Gen Assy	Eng	492	493	SN Fired	492	493	492	493
705574-39	GGFCKV	Eng	492	493	SN Fired	504	506	504	506
702642-59	GGOCKV	Eng	492	493	SN Fired	871	872	872	871
259387	FBTL	Eng	492	493	SN Fired	540	543	540	543
1131888-1	OBTL	Eng	492	493	SN Fired	1604	1605	1604	1605
1131273-9	TCA	Eng		D-14	SN Fired	475	476	475	476
1130063-19	TCOV	TCA	475	476	SN Fired	606	604	606	604
1130064-9	TCFV		475	476	SN Fired	674	676	674	676
1131736	PSV		475	476	SN Fired	643	644	643	644
255662-29	Fuel Elbow (U/S)		475	476	SN Fired	730	731	730	731
285992-9	Fuel Elbow (O/S)		475	476	SN Fired	236	237	236	237
1131576-1	Ox Elbow		475	476	SN Fired	007	003	007	003
1129532-39	Gimbal Assy		475	476	SN Fired	003	002	003	002
1130174-79	Combustion Chamber		475	476	SN Fired	017	019	017	1133311-19(19 / 092

Stage I Engine Time-Cycle Log Engine S/N 14 (cont.)

51-D07-1A-209		3051-D07-1A-210		3051-D07-1A-211		3051-D07-1A-212		3051-D07-1A-213		3051-D07-1A-214	
7-1-68		7-5-68		7-5-68		7-12-68		7-16-68		7-22-68	
20.575 (N_2)		200.315 (S)		20.744 (N_2)		201.006 (S)		20.762 (N_2)		201.013 (S)	
1	2	1	2	1	2	1	2	1	2	1	2
605	-	605	-	605	-	605	-	605	-	605	-
054	131	054	131	054	131	054	131	054	131	054	131
476	478	476	478	476	478	476	478	476	478	476	478
695	647	695	647	695	647	1122210-9 / 721	1122214-9 / 722	695	647	695	647
625[18]	624[18]	625	624	625	624	625	624	625	624	625	624
378	376	378	376	376[20]	378[20]	376	378	378[22]	376[22]	378	376
-	755	-	755	-	755	-	755	-	755	-	755
492	493	492	493	492	493	492	493	492	493	492	493
492	493	492	493	492	493	492	493	492	493	492	493
504	506	504	506	504	506	504	506	504	506	504	506
872	871	872	871	871	872	871	872	871	872	871	872
540	543	540	543	540	543	540	543	540	543	540	543
604	1605	1604	1605	1604	1605	1604	1605	1604	1605	1604	1605
475	476	475	476	475	476	475	476	475	476	475	476
606	604	606	604	606	604	606	604	606	604	606	604
674	676	674	676	674	676	674	676	674	676	674	676
643	644	643	644	643	644	643	644	643	644	643	644
730	731	730	731	730	731	730	731	730	731	730	731
236	237	236	237	236	237	236	237	236	237	236	237
007	003	007	003	007	003	007	003	007	003	007	003
003	002	003	002	003	002	003	002	003	002	003	002
017	1133311-19(19) / 092	017	092	017	092	017	092	017	092	017	092

2

Table I --Titan IIIM Stage I Engine Time-C

Part No.	Name	Top Assembly Name	Top Assembly S/N		Test Date Dur. S/A	3051-D07-1A-215 8-27-68 200.458 (S) 1	2
1129050-19	Frame Assy	Eng	D-14		SN Fired	605	---
256866-19	Fuel Disch. Line	Eng	D-14		SN Fired	054	131
265382-19	Ox Disch. Line	Eng	D-14		SN Fired	476	478
294252/ 255639	Fuel Suct. Line	Eng	D-14		SN Fired	41600-1 / 37	647
294251	Ox Suct. Line	Eng	D-14		SN Fired	624	628
261885-39	Fluid Heater	Eng	D-14		SN Fired	378	376
224899-19	Hot Gas Cooler	Eng	D-14		SN Fired	---	755
709987-19	Gas Gen Assy	Eng	D-14		SN Fired	492	493
250375-19	Gas Gen Assy	Eng	492	493	SN Fired	492	493
705574-59	GGFCKV	Eng	492	493	SN Fired	X8230-16MA / X-1	506
702642-59	GGOCKV	Eng	492	493	SN Fired	871	872
259387	FBTL	Eng	492	493	SN Fired	540	543
1131888-1	OBTL	Eng	492	493	SN Fired	1604	1605
1131273-9	TCA	Eng	D-14		SN Fired	475	476
1130063-19	TCOV	TCA	475	476	SN Fired	606	604
1130064-9	TCFV		475	476	SN Fired	674	676
1131736	PSV		475	476	SN Fired	643	644
255662-29	Fuel Elbow (U/S)		475	476	SN Fired	730	731
285992-9	Fuel Elbow (O/S)		475	476	SN Fired	236	237
1131576-1	Ox Elbow		475	476	SN Fired	007	003
1129532-39	Gimbal Assy		475	476	SN Fired	003	002
1130174-79	Combustion Chamber		475	476	SN Fired	017	092

I --Titan IIIM Stage I Engine Time-Cycle Log Engine S/N 14 (cont.)

-D07-1A-215
8-27-68
00.458 (S)

	2

	131
	478
1	647
	628
	376
	755
	493
	493
6MA	506
	872
	543
	1605
	476
	604
	676
	644
	731
	237
	003
	002
	092

2

Table I --Titan IIIM Stage 1 Engine Time-Cy

Part No.	Name	Top Assembly Name	S/N		Test Date Dur. S/A	3051-D07-1A-201 12-20-67 19.657 (N_2) 1	2	3051-D07-1A-202 12-29-67 200 825 (S) 1	2	3051-D0 1-1 200.5 1
1130409-129	Injector	TCA	475	476	SN Fired	(1)697	(2)696	697	696	697
706472-19	TCPS	TCA	475	476	SN Fired	1417	1416	1417	1416	1417
706472-19	TCPS	TCA	475	476	SN Fired	1418	1415	1418	1415	1418
1131352-39	TPA	Eng	D-14		SN Fired	008	010	008	010	008
286706-9	OX Pump Hsg	TPA	008	010	SN Fired	(3)825	(4)799	825	799	825
286707-9	Fuel Pump Hsg	TPA	008	010	SN Fired	(3)915	(4)924	915	924	915
246626-5	Ox Pump Impeller	TPA	008	010	SN Fired	(3)2894	(4)856	2894	956	2894
246627-5	Fuel Pump Impeller	TPA	008	010	SN Fired	(3)2898	(4)2860	2898	2860	2892
291377-19	Ox Pump Seal	TPA	008	010	SN Fired	(3)1349	(4)1346	1349	1346	1349
291378-9	Fuel Pump Seal	TPA	008	010	SN Fired	(3)1354	(4)1355	1354	1355	1354
1132400-9	Turbine GB Seal	TPA	008	010	SN Fired	(5)4741	(6)4744	4741	4744	4741
260825-11	2nd Stage Nozzle	TPA	008	010	SN Fired	(3)658	(4)660	658	660	658
a. 1130119-1	1st Stage Rotor	TPA	008	010	SN Fired	-	(4)607	-	-	-
b. 1130983-1	1st Stage Rotor	TPA	008	010	SN Fired	(3)164	-	622(7)	624	622
a. 1130120-3	2nd Stage Rotor	TPA	008	010	SN Fired	(3)799	(4)797	-	-	-
b. 1130974-1	2nd Stage Rotor	TPA	008	010	SN Fired	-	-	002(7)	003	002
1122654-59	Turbine Manifold	TPA	008	010	SN Fired	(3)045	(4)041	045	041	045
1131351-59	Gearbox Assy	TPA	008	010	SN Fired	(5)387	(6)389	387	389	387
1130976-29	Turbine Rotor Bolt	TPA	008	010	SN Fired	(3)055	(4)060	056	061	056
1130728-3	Lube Oil Cooler	TPA	008	010	SN Fired	(3)012	(4)013	012	013	012
	Ablative Skirt	TCA	475	476	SN Fired	-	-	-	-	-

1

tage I Engine Time-Cycle Log Engine S/N 14 (cont.)

-D07-1A-202 2-29-67 0.825 (S)		3051-D07-1A-203 1-10-68 200.585 (S)		3051-D07-1A-204 3-11-68 115.438 (S)		3051-D07-1A-205 4-4-68 20.851 (N_2)		3051-D07-1A-206 4-10-68 200.925 (S)		3051-D07-1A-207 4-29-68 200.599 (S)	
	2	1	2	1	2	1	2	1	2	1	2
97	696	697	696	697	696	697	696	697	696	697	696
17	1416	1417	1416	1417	1416	1417	1416	1417	1416	1417	1416
18	1415	1418	1415	1418	1415	1418	1415	1418	1415	1418	1415
08	010	008	010	008	010	008	006[15]	008	006	008	006
25	799	825	799	825	799	825	282197/656	825	656	825	656
15	924	915	924	915	924	915	282185/664	915	664	915	664
94	956	2894	956	2894	856	2894	2548	2894	2548	2894	2548
98	2860	2892	2860	2898	2860	2898	2859	2898	2859	2898	2859
49	1346	1349	1346	1349	1346	1349	1320	1349	1320	1349	1320
54	1355	1354	1355	1354	1355	1354	1340	1354	1340	1354	1340
41	4744	4741	4744	4741	4744	4741	4742	4741	4742	4741	4742
58	660	658	660	658	660	665[16]	596[13]	665	596	665	596
-	-	-	-	-	-	-	-	-	-	-	-
22[7]	624	622	638[8]	637[9]	638	006[11]	004[12]	006	004	006	004
-	-	-	-	-	-	-	-	-	-	-	-
002[7]	003	002	008[8]	005[9]	008	895[16]	810	895	810	805	
045	041	045	041	045	046	045	046	045	046	045	
387	389	387	389	387	389	387	155[14]	387	155	367	155
056	061	056	061	056	061	056	053	056	053	054	
012	013	012	013	012	006	116[16]	171	116	173	116	
-	-	-	-	1129770-19/925	1129770-19/037	-	-	1129770-19/025	1129770-19/037	-	-

2

Table I --Titan IIIM Stage I Engine Time-Cyc

Part No.	Name	Top Assembly Name	Top Assembly S/N		Test Date Dur. S/N	3051-D07-1A-208 5-4-68 21.215 (N_2) 1	2	3051-D07-1A-209 7-1-68 20.575 (N_2) 1	2	3051-D 7- 2 1
1129910-17	Dome Assy		475	476	SN Fired	523	522	523	522	523
1130409-129	Injector		475	476	SN Fired	697	696	697	696	697
706472-19	TCPS		475	476	SN Fired	1417	1416	1417	1416	1417
706472-19	TCPS		475	476	SN Fired	1418	1415	1418	1415	1418
1131352-39	TPA	Eng	D-14		SN Fired	008	006	008	006	008
286706-9	Ox Pump Hsg	TPA	008	006	SN Fired	825	282197/656	825	656	825
286707-9	Fuel Pump Hsg		008	006	SN Fired	915	282185/664	915	664	915
246626-5	Ox Pump Impeller		008	006	SN Fired	2894	2548	2894	2548	2894
246627-5	Fuel Pump Impeller		008	006	SN Fired	2898	2859	2898	2859	2898
291377-19	Ox Pump Seal		008	006	SN Fired	1349	1320	1349	1320	1349
291378-9	Fuel Pump Seal		008	006	SN Fired	1354	1340	1354	1340	1354
1132400-9	Turbine GB Seal		008	006	SN Fired	4741	4742	4793	4874	4793
260825-11	2nd Stage Nozzle		008	006	SN Fired	665	596	665	596	665
a. 1130119-1	1st Stage Rotor	TPA	008	006	SN Fired	-	-	-	-	-
b. 1130983-1	1st Stage Rotor	TPA	008	006	SN Fired	006	004	006	004	006
a. 1130120-3	2nd Stage Rotor	TPA	008	006	SN Fired	-	-	-	-	-
b. 1130974-1	2nd Stage Rotor	TPA	008	006	SN Fired	895	810	895	810	895
1122654-59	Turbine Manifold	TPA	008	006	SN Fired	045	046	045	046	045
1131351-59	Gearbox Assy	TPA	008	006	SN Fired	387	155	387	155	387
1130976-29	Turbine Rotor Bolt	TPA	008	006	SN Fired	056	053	056	053	056
1130728-3	Lube Oil Cooler	TPA	008	006	SN Fired	116	171	116	171	116
	Ablative Skirt	TCA	475	476	SN Fired	-	-	-	-	-

1

Stage I Engine Time-Cycle Log Engine S/N 14 (cont.)

051-D07-1A-209		3051-D07-1A-210		3051-D07-1A-211		3051-D07-1A-212		3051-D07-1A-213		3051-D07-1A-214	
7-1-68		7-5-68		7-10-68		7-12-68		7-16-68		7-22-68	
20.575 (N_2)		200.315 (S)		20.744 (N_2)		201.006 (S)		20.762 (N_2)		201.013 (S)	
1	2	1	2	1	2	1	2	1	2	1	2
523	522	523	522	523	522	523	522	523	522	523	522
697	696	697	696	697	696	297	696	697	696	697	696
1417	1416	1417	1416	1417	1416	1417	1416	1417	1416	1417	1416
1418	1415	1418	1415	1418	1415	1418	1415	1418	1415	1418	1415
008	006	008	006	008	006	008	006	008	006	008	006
825	656	825	656	825	656	825	656	825	656	825	656
915	664	915	664	915	664	915	664	915	664	915	664
2894	2548	2894	2548	2894	2548	2894	2548	2894	2548	2894	2548
2898	2859	2898	2859	2898	2859	2898	2859	2898	2859	2898	2859
1349	1320	1349	1320	1349	1320	1349	1320	1349	1320	1349	1320
1354	1340	1354	1340	1354	1340	1354	1340	1354	1340	1354	1340
4793	4874	4793	4874	4793	4874	4793	4874	4793	4874	4793	4874
665	596	665	596	685 (21)	745 (21)	685	745	685	745	685	745
-	-	-	-	-	-	-	-	-	-	-	-
006	004	006	004	006	004	006	004	006	004	006	004
-	-	-	-	-	-	-	-	-	-	-	-
895	810	895	810	895	810	895	810	895	810	895	810
045	046	045	046	045	046	045	046	045	046	045	046
387	155	387	155	387	155	387	155	387	155	387	155
056	053	056	053	056	053	056	053	056	053	056	053
116	171	116	171	116	171	116	171	116	171	116	171
-	-	-	-	-	-	-	-	-	-		

2

Table I --Titan IIIM Stage I Engine Time-Cy

Part No.	Name	Top Assembly Name	S/N		Test Date Dur. S/A	3051-D07-1A-215 8-27-68 200.458 (S) 1	2
1129910-17	Dome Assy		475	476	SN Fired	523	522
1130409-129	Injector		475	476	SN Fired	697	696
706472-19	TCPS		475	476	SN Fired	1417	1416
706472-19	TCPS		475	476	SN Fired	1418	1415
1131352-39	TPA	Eng	D-14		SN Fired	008	006
286706-9	Ox Pump Hsg	TPA	008	006	SN Fired	825	656
286707-9	Fuel Pump Hsg		008	006	SN Fired	915	664
246626-5	Ox Pump Impeller		008	006	SN Fired	2894	2548
246627-5	Fuel Pump Impeller		008	006	SN Fired	2898	2859
291377-19	Ox Pump Seal		008	006	SN Fired	1349	1320
291378-9	Fuel Pump Seal		008	006	SN Fired	1354	1340
1132400-9	Turbine GB Seal		008	006	SN Fired	4793	4874
26082[illegible]-11	2nd Stage Nozzle		008	006	SN Fired	685	745
a. 1130119-1	1st Stage Rotor	TPA	008	006	SN Fired	---	---
b. 1130983-1	1st Stage Rotor	TPA	008	006	SN Fired	006	004
a. 1130120-3	2nd Stage Rotor	TPA	008	006	SN Fired	---	---
b. 1130974-1	2nd Stage Rotor	TPA	008	006	SN Fired	895	810
1122654-59	Turbine Manifold	TPA	008	006	SN Fired	045	046
1131351-59	Gearbox Assy	TPA	008	006	SN Fired	387	155
1130976-29	Turbine Rotor Bolt	TPA	008	006	SN Fired	056	053
1130728-3	Lube Oil Cooler	TPA	008	006	SN Fired	116	171
	Ablative Skirt	TCA	475	476	SN Fired	032	033

(1) Injector S/
(2) Injector S/
(3) These compo for 200.00
(4) These compo for 200.08
(5) These compo at WGC - 40
(6) These compo at WGC - 40
(7) Fired on te
(8) Fired on te
(9) Fired on te
(10) Hot gas coo
(11) 1st Stage r and has tota
(12) 1st Stage r and has tota
(13) 2nd Stage n 202.19 sec a
(14) Gearbox S/N (includes 20
(15) TPA 006 and and 7 cycles
(16) These compon
(17) Combustion c
(18) OSL's switch
(19) Combustion c
(20) Superheaters
(21) 2nd Stage no
(22) Superheaters

ltan IIIM Stage I Engine Time-Cycle Log Engine S/N 14 (cont.)

-1A-215
58
58 (S)
2

522
696
1416
1415
006
656
664
2548
2859
1320
1340
4874
745

004

810
046
155
053
171
033

Notes

(1) Injector S/N 697 - 121.10 sec and 2 cycles. Prior usage.

(2) Injector S/N 696 - 121.10 sec and 2 cycles. Prior usage.

(3) These components were fired with TPA 008 on test 3051-A01-1P-002 for 200.00 sec and 1 cycle (10-28-67)

(4) These components were fired with TPA 010 on test 3051-A01-1P-003 for 200.08 sec and 1 cycle. (11-4-67)

(5) These components experienced a cold flow test and full load test at WGC - 400.00 sec and 2 cycles.

(6) These components experienced a cold flow test and full load test at WGC - 400.08 sec and 2 cycles.

(7) Fired on test 3051-A01-1P-004 for 200.01 sec.

(8) Fired on test 3051-A01-1P-006 for 200.12 sec.

(9) Fired on test 3051-A01-1P-007 for 199.99 sec.

(10) Hot gas cooler S/N 755 is a P/N 1154573. No prior time recorded.

(11) 1st Stage rotor S/N 006 is a P/N 1154300-5 (83-blade configuration), and has total prior time of 1212.91 sec and 6 cycles.

(12) 1st Stage rotor S/N 004 is a P/N 1154950-1 (83-blade configuration), and has total prior time of 202.19 sec and 1 cycle.

(13) 2nd Stage nozzle S/N 596 was fired on test 3051-D18-1P-001 for 202.19 sec and 1 cycle.

(14) Gearbox S/N 155 has a total time of 1709.36 sec and 8 cycles (includes 200 sec test at WGC).

(15) TPA 006 and internal components have a total time of 1509.36 sec and 7 cycles unless otherwise noted.

(16) These components have no recorded prior usage.

(17) Combustion chambers switched subassemblies.

(18) OSL's switched subassemblies.

(19) Combustion chamber P/N 1133311-19, S/N 092 is a Titan III B/C/D chamber.

(20) Superheaters installed on opposite subassemblies from test -210.

(21) 2nd Stage nozzles P/N 260825-11, S/N 685 and S/N 745 have no prior usage.

(22) Superheaters reinstalled on original subassemblies pretest -213.

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Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine S

Part Number	Name	Top Assembly Name	Top Assembly SN	Test Date Dur. SA	3051-D07-1A-301 6-3-68 20.669 (N2) 1	2	3051-D07-1A-302 6-6-68 201.088 (S) 1	2	305 2 1
1129050-19	Frame Assembly	Eng	D-15	SN Fired	606	-	606	-	6
1133576-19	Fuel Disch. Line				539	542	539	542	5
1133568-19	Oxid Disch. Line				554	555	554	555	5
294252/255639-19	Fuel Suct. Line				696	648	696	648	6
294251	Oxid Suct. Line				623	626	623	626	6
261285-39	Fluid Heater				190	375	190	375	1
1154573-1	Hot Gas Cooler				---	754	---	754	-
709987-19	Gas Gen. Assy				480	491	480	491	4
250375-79	Gas Gen. Chamber	GGA	480/491		480	491	480	491	4
705574-39	GGFCKV		480/491		505	507	505	507	5
702642-59	GGOCKV		480/491		873	870	873	870	8
259387	FBTL		480/491		541	542	541	542	5
1131888-1	OBTL		480/491		1,608	1,609	1,608	1,609	1,6
1131273-9	TCA	Eng	D-15		477	478	477	478	4
1130063-19	TCOV	TCA	477/478		605	607	605	607	6
1130064-9	TCFV		477/478		677	675	677	675	6
1131736-9	PSV		477/478		640	642	640	642	6
255662-29	Fuel Elbow (U/S)		477/478		728	729	728	729	7
1131273-7	Fuel Elbow (D/S)		477/478		273	478	273	478	2

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Log, Engine S/N 15

-1A-302	3051-D07-1A-303		3051-D07-1A-304		3051-D07-1A-305		3051-D07-1A-306		3051-D07-1A-307	
68	6-14-68		6-18-68		6-24-68		7-26-68		8-1-68	
8 (S)	200.341 (S)		200.843 (S)		200.645 (S)		200.746 (S)		200.470 (S)	
2	1	2	1	2	1	2	1	2	1	2
-	606	-	606	-	606	-	606	-	606	-
542	539	542	539	542	539	542	539	542	539	542
555	554	555	554	555	554	555	554	555	554	555
648	696	648	696	648	696	648	696	648	696	648
626	623	626	623	626	623	626	623	626	623	626
375	190	375	190	375	190	375	190	375	190	375
754	---	754	---	754	---	754	-	754	-	754
491	480	491	480	491	480	491	480	491	480	491
491	480	491	480	491	480	491	480	491	480	491
507	505	507	505	507	505	507	505	507	505	507
870	873	870	873	870	873	870	873	870	873	870
542	541	542	541	542 (12)	541	536 (11)	541	536	541	536
1,609	1,608	1,609	1,608	1,609	1,608	1,609	1,608	1,609	1,608	1,609
478	477	478	477	478	477	478	477	478	477	478
607	605	607	605	607	605	607	605	607	605	607
675	677	675	677	675	677	675	677	675	677	675
642	640	642	640	642	640	642	640	642	640	642
729	728	729	728	729	728	729	728	729	728	729
478	273	478	273	478	273	478	273	478	273	478

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Table XI -- Titan IIIM Stage I Engine Time-Cycle Log, Engine S

				Test	3051-D07-1A-308		3051-D07-1A-309		30
				Date	8-14-68		8-15-68		
				Dur.	20.977 (N2)		(15) 2.569 (S)		
Part Number	Name	Name	SN	SA	1	2	1	2	
1129050-19	Frame Assembly	Eng	D-15	SN	606	---	606	---	
1155576-19	Fuel Disch. Line			Fired	539	542	539	542	
1133568-19	Oxid. Disch. Line				554	555	554	555	
					1122210-9	1122214-9	1122210-9	1122210-9	
294252/255639-19	Fuel Suction Line				696	648	721	704	
294251	Oxid. Suction Line				623	626	623	626	
261285-39	Fluid Heater				190	375	190	375	
1154573-1	Hot Gas Cooler				---	754	---	754	
709987-19	Gas Gen. Assembly				480	491	480	491	
250375-79	Gas Gen. Assembly	GGA	480/491		480	491	480	491	
705574-39	GGFCKV		480/491		505	507	505	507	
702642-59	GGDCKV		480/491		873	870	873	870	
259387	FBTL		480/491		541	536	541	536	
1131888-1	OBTL		480/491		1,608	1,609	1,608	1,609	1,
1131273-9	TCA	Eng	D-15		477	478	477[16]	478	
1130063-19	TCOV	TCA	477/478		605	607	605[16]	607	
1130064-9	TCFV		477/478		677	675	677[16]	675	
1131736-9	PSV		477/478		640	642	640[15][16]	642	
255662-29	Fuel Elbow (U/S)		477/478		728	729	728[16]	729	
1131273-7	Fuel Elbow (D/S)		477/478		273	478	273[16]	478	

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Engine S/N 15 (cont.)

-309	3051-D07-1A-310 8-16-68 200.361 (S)		3051-D07-1A-311 9-17-68 21.340 (N2)		3051-D07-1A-312 9-19-68 201.114 (S)		3051-D07-1A-313 9-28-68 20.485 (N2)		3051-D07-1A-314 10-1-68 200.908 (S)	
(S) 2	1	2	1	2	1	2	1	2	1	2
---	606	---	606	---	606	---	606	---	606	---
542	539	542	539	542	539	542	539	542	539	542
555	554	555	554	555	554	555	554	555	554	555
1122210-9					1122210-9	1122214-9			1122210-9	1122214-9
704	721	704	696	648	721	704	696	648	721	704
626	623	626	623	626	623	626	623	626	623	626
375	190	375	190	375	190	375	190	375	190	375
754	---	754	---	754	---	754	---	754	---	754
491	480	491	480	491	480	491	480	491	480	491
491	480	491	480	491	480	491	480	491	480	491
507	505	507	505	507	505	507	505	507	505	507
870	873	870	873	870	873	870	873	870	873	870
536	541	536	541	536	541	536	541	536	541	536
,609	1,608	1,609	1,608	1,609	1,608	1,609	1,609	1,608	1,608	1,609
478	477	478	477	478	477	478	477	478	477	478
607	605	607	605	607	605	607	605	607	605	607
675	677	675	677	675	677	675	677	675	677	675
642	641	642	641	642	641	642	641	642	641	642
729	728	729	728	729	728	729	728	729	728	729
478	273	478	273	478	273	478	273	478	273	478

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Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine

Part Number	Name	Top Assembly Name	Top Assembly SN	Test / Date / Dur. / SA	3051-D07-1A-315 / 10-3-68 / 21.095 (N2) / 1	2	3051-D07-1A-316 / 10-17-68 / 200.809 (S) / 1	2
1129050-19	Frame Assy	Eng	D-15	SN Fired	606	---	606	---
1133576-19	Fuel Disch. Line				539	542	539	542
1133568-19	Oxid. Disch. Line				554	555	554	555
							1122210-9	1122214-9
294252/255639-19	Fuel Suct. Line				696	648	721	704
294251	Oxid. Suct. Line				623	626	623	626
261285-39	Fluid Heater				190	375	190	375
1154573-1	Hot Gas Cooler				---	754	---	754
709987-19	Gas Gen. Assy				480	491	480	491
250375-79	Gas Gen. Chamber	GGA	480/491		480	491	480	491
705574-39	GGFCKV		480/491		505	507	505	507
702642-59	GGOCKV		480/491		873	870	873	870
259387	FBTL		480/491		541	536	541	536
1131888-1	OBTL		480/491		1,608	1,609	1,608	1,609
1131273-9	TCA	Eng	D-15		477	478	477	478
1130063-19	TCOV	TCA	477/478		605	607	605	607
1130064-9	TCFV		477/478		677	675	677	675
1131736-9	PSV		477/478		641	642	641	642
255662-29	Fuel Elbow (U/S)		477/478		728	729	728	729
1131273-7	Fuel Elbow (D/S)		477/478		273	478	273	478

ge I Engine Time-Cycle Log, Engine S/N 15 (cont.)

-D07-1A-315 10-3-68 .095 (N2)		3051-D07-1A-316 10-17-68 200.809 (S)											
	2	1	2	1	2	1	2	1	2	1	2	1	2
06	---	606	---										
39	542	539	542										
54	555	554	555										
		1122210-9	1122214-9										
96	648	721	704										
23	626	623	626										
90	375	190	375										
--	754	---	754										
80	491	480	491										
80	491	480	491										
05	507	505	507										
73	870	873	870										
41	536	541	536										
08	1,609	1,608	1,609										
77	478	477	478										
05	607	605	607										
77	675	677	675										
41	642	641	642										
28	729	728	729										
73	478	273	478										

2

Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engi

Part Number	Name	Top Assembly Name	Top Assembly SN	Test Date Dur. SA	3051-D07-1A-301 6-3-68 20.669 (N2) 1	2	3051-D07-1A-302 6-6-68 201.088 (S) 1	2
1131576-1	Oxid Elbow		477/478		005	006	005	006
1129532	Gimbal Assy		477/478		001	004	001	004
1133311-19	Comb. Chamber		477/478		021	022	021	022
1155273-1	Dome Assy		477/478		004	002	004	002
1130409-129	Injector		477/478		699	698	699	698
706472-19	TCPS		477/478		1,411	1,414	1,411	1,414
706472-19	TCPS		477/478		1,410	1,413	1,410	1,413
See Applicable Test for Skirt PNs	Ablative Skirt		477/478		---	---	---	---
1131352-139	TPA	Eng	D-15		009 (3)	011 (4)	009	011
286706-9	Ox Pump Hsg.	TPA	009/011		826	810	826	810
286707-9	Fuel Pump Hsg.		009/011		910	923	910	923
246626-5	Ox Pump Impeller		009/011		2,893	2,892	2,893	2,892
246627-5	Fuel Pump Impeller		009/011		2,895	2,896	2,895	2,896
291377-19	Ox Pump Seal		009/011		1,350	1,348	1,350	1,348
291378-9	Fuel Pump Seal		009/011		1,353	1,351	1,353	1,351
1132400-9	Turbine GB Seal		009/011		4,873 (5)	4,869 (6)	4,873	4,869

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Log, Engine S/N 15 (cont.)

-1A-302 -68 8 (S)	3051-D07-1A-303 6-14-68 200.341 (S)		3051-D07-1A-304 6-18-68 200.843 (S)		3051-D07-1A-305 6-24-68 200.645 (S)		3051-D07-1A-306 7-26-68 200.746 (S)		3051-D07-1A-307 8-1-68 200.470 (S)	
2	1	2	1	2	1	2	1	2	1	2
006	005	006	005	006	005	006	005	006	005	006
004	001	004	001	004	001	004	001	004	001	004
022	021	022	021	022	021	022	021	022	021	022
002	004	002	004	002	004	002	004	002	004	002
698	699	698	699	698	699	698	699	698	699	698
1,414	1,411	1,414	1,411	1,414	1,411	1,414	1,411	1,414	1,411	1,414
1,413	1,410	1,413	1,410	1,413	1,410	1,413	1,410	1,413	1,410	1,413
---	---	---	---	---	1154627-9 035	1129770-19 038	---	---	1121077 014	1129770 021
011	009	011	099	011	009	011	009	011	009	011
810	826	810	826	810	826	810	826	810	826	810
923	910	923	910	923	910	923	910	923	910	923
2,892	2,893	2,892	2,893	2,892	2,893	2,892	2,893	2,892	2,883	2,892
2,896	2,895	2,896	2,895	2,896	2,895	2,896	2,895	2,896	2,895	2,896
1,348	1,350	1,348	1,350	1,348	1,350	1,348	1,350	1,348	1,350	1,348
1,351	1,353	1,351	1,353	1,351	1,353	1,351	1,353	1,351	1,353	1,351
4,869	4,873	4,869	4,873	4,869	4,873	4,869	4,873	4,869	4,873	4,889

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Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine S

				Test	3051-D07-1A-308		3051-D07-1A-309	
				Date	8-14-68		8-15-68	
				Dur.	20.977 (N2)		(15) 2.569 (S)	
Part Number	Name	Name	SN	SA	1	2	1	2
1131576-1	Oxid. Elbow		477/478		005	006	005[16]	006
1129532	Gimbal Assy.		477/478		001	004	001[16]	004
1133311-19	Comb. Chamber		477/478		021	022	021[16]	022
1155273-1	Dome Assembly		477/478		004	002	004[16]	002
1130409-129	Injector		477/478		699	698	699[16]	698
706472-19	TCPS		477/478		1,411	1,414	1,411[16]	1,414
706472-19	TCPS		477/478		1,410	1,413	1,410[16]	1,413
See applicable test for Skirt PNs	Ablative Skirt		477/478		---	---	---	---
1131352-139	TPA	Eng	D-15		009	011	009	011
286706-9	Oxid. Pump Hsg	TPA	009/011		826	810	826	810
286707-9	Fuel Pump Hsg		009/011		910	923	910	923
246626-5	Oxid. Pump Impeller		009/011		2,893	2,892	2,893	2,892
246627-5	Fuel Pump Impeller		009/011		2,895	2,896	2,895	2,896
291277-19	Oxid. Pump Seal		009/011		1,350	1,348	1,350	1,348
291378-9	Fuel Pump Seal		009/011		1,353	1,351	1,353	1,351
1132400-9	Turbine GB Seal		009/011		4,873	4,869	4,873	4,869

, Engine S/N 15 (cont.)

-1A-309 -68 69 (S)	3051-D07-1A-310 8-16-68 200.361 (S)		3051-D07-1A-311 9-17-68 21.340 (N2)		3051-D07-1A-312 9-19-68 201.114 (S)		3051-D07-1A-313 9-28-68 20.485 (N2)		3051-D07-1A-314 10-1-68 200.908 (S)	
2	1	2	1	2	1	2	1	2	1	2
006	005	006	005	006	005	006	005	006	005	006
004	001	004	001	004	001	004	001	004	001	004
022	021	022	021	022	021	022	021	022	021	022
002	004	002	004	002	004	002	004	022	004	002
698	699	698	699	698	699	698	699	698	699	698
1,414	1,411	1,414	1,411	1,414	1,411	1,414	1,411	1,414	1,411	1,414
1,413	1,410	1,413	1,410	1,413	1,410	1,413	1,410	1,413	1,410	1,413
---	---	---	---	---	---	---	---	---	---	---
011	009	011	009	011	009	011	009	011	009	011
810	826	810	826	810	826	810	826	810	826	810
923	910	923	910	923	910	923	910	923	910	923
2,892	2,893	2,892	2,893	2,892	2,893	2,892	2,893	2,892	2,893	2,892
2,896	2,895	2,896	2,895	2,896	2,895	2,896	2,895	2,896	2,895	2,896
1,348	1,350	1,348	1,364	1,363	1,364	1,363	1,364	1,363	1,364	1,363
1,351	1,353	1,351	1,353	1,351	1,353	1,351	1,353	1,351	1,353	1,351
4,869	4,873	4,869	4,873	4,869	4,873	4,869	4,873	4,869	4,873	4,869

2

Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engin

Part Number	Name	Top Assembly Name	Top Assembly SN	Test Date Dur. SA	3051-D07-1A-315 10-3-68 21.095 (N2) 1	2	3051-D07-1A-316 10-17-68 200.809 (S) 1	2
1131576-1	Oxid. Elbow		477/478		005	006	005	006
1129532	Gimbal Assy		477/478		001	004	001	004
1133311-19	Comb. Chamber		477/478		021	022	021	022
1155273-1	Dome Assy		477/478		004	002	004	002
1130409-129	Injector		477/478		699	698	699	698
706472-19	TCPS		477/478		1,411	1,414	1,411	1,414
706472-19	TCPS		477/478		1,410	1,413	1,410	1,413
See Applicable Test for Skirt PNs	Ablative Skirt		477/478		---	---	1155706-1 039	115570 040
1131352-139	TPA	Eng	D-15		009	011	009	011
286706-9	Ox Pump Hsg.		009/011		826	810	826	810
286707-9	Fuel Pump Hsg.		009/011		910	923	910	923
246626-5	Ox Pump Impeller		009/011		2,893	2,892	2,893	2,892
246627-5	Fuel Pump Impeller		009/011		2,895	2,896	2,895	2,896
291377-19	Ox Pump Seal		009/011		1,364	1,363	1,364	1,363
291378-9	Fuel Pump Seal		009/011		1,353	1,351	1,353	1,351
1132400-9	Turbine GB Seal		009/011		4,873	4,869	4,873	4,869

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Engine Time-Cycle Log, Engine S/N 15 (cont.)

D07-1A-315	3051-D07-1A-316											
0-3-68	10-17-68											
095 (N2)	200.809 (S)											
2	1	2	1	2	1	2	1	2	1	2	1	2
006	005	006										
004	001	004										
022	021	022										
002	004	002										
698	699	698										
1,414	1,411	1,414										
1,413	1,410	1,413										
---	1155706-1 039	1155706-1 040										
011	009	011										
810	826	810										
923	910	923										
2,892	2,893	2,892										
2,896	2,895	2,896										
1,363	1,364	1,363										
1,351	1,353	1,351										
4,869	4,873	4,869										

2

Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine S

Part Number	Name	Top Assembly Name	Top Assembly SN	Test / Date / Dur. / SA	3051-D07-1A-301 6-3-68 20.669 (N2) 1	2	3051-D07-1A-302 6-6-68 201.008 (S) 1	2	305 2 1
260825-11	2nd Stage Nozzle	TPA	009/011	SN	662	333	662	333	6
1154950-1	1st Stage Rotor		009/011	Fired	001 (1)	759 (2)	001	759	0
1120074-2	2nd Stage Rotor		009/011		896 (1)	807 (2)	896	807	8
1122654-59	Turbine Manifold		009/011		047	048	047	048	0
1131351-59	Gearbox Assembly		009/011		388 (9)	390 (10)	388	390	3
1130728-3	Lube Oil Cooler		009/011		164 (7)	165 (8)	164	165	1
1130976-29	Turbine Rotor Bolt		009/011		051	055	051	055	0
1155001-1	Exit Closure	TCA	477/478		---	---	---	---	-

Notes: (1) 1st Stage Rotor, PN 1154950-1, SN 001 was fired on Test 3051-D18-1P-002 for 200.990 sec (th the same time is applicable to 2nd Stage Rotor SN 896.

(2) 1st Stage Rotor, PN 1154950-1, SN 759 was fired on Test 3051-D18-1P-003 for 10.140 sec (thi The same time is applicable to 2nd Stage Rotor SN 807.

(3) TPA SN 009 and components have prior usage (except where noted) of 297.830 sec/2 cycles.

(4) TPA SN 011 and components have prior usage (except where noted) of 202.430 sec/1 cycle.

(5) Turbine Gearbox Seal SN 4873 was installed on TPA 009 on 4-25-68. The seal has no prior us

(6) Turbine Gearbox Seal SN 4869 was installed on TPA 011 on 4-23-68. The seal has no prior us

(7) Lube Oil Cooler SN 164 was installed on TPA 009 on 4-24-68. The cooler has no prior usage.

(8) Lube Oil Cooler SN 165 was installed on TPA 011 on 4-24-68. The cooler has no prior usage.

(9) Gearbox SN 388 has a total accumulated time/cycle of 497.830 sec/3 cycles, including tests test at Western Gear Corporation.

(10) Gearbox SN 390 has a total accumulated time/cycle of 402.430 sec/2 cycles, including tests test at Western Gear Corporation.

(11) Installed posttest 304 due to leakage of SN 542. New line with no prior usage.

(12) Time to failure was 623.109 seconds and 4 cycles hot fire.

(13) Oxidizer Pump Seal SN 1350 had straight thru leakage posttest 308. Accepted for further te

(14) Oxidizer Pump Seal SN 1348 had straight thru leakage posttest 308. Accepted for further te

(15) SA-1 failed to start due to stuck PSVOR. PSV SN 640 removed. Time to failure was 1246.181

(16) Reference Note (15): These components did not see hot fire because of failure of thrust ch cycle recording purposes these components will have 1 test less accumulated time/cycles tha

(17) These components installed posttest 310. They have no prior usage.

(18) The 1st Stage Rotors were installed posttest 310. They are -2 configuration and have no pr

(19) Gearbox SN 388 (TPA 009) was reworked posttest 310. For parts replacements refer to IR-469

(20) Gearbox SN 390 (TPA 011) was reworked posttest 310. For parts replacements refer to IR-469

1

Log, Engine S/N 15 (cont.)

7-1A-302 -68 08 (S)	3051-D07-1A-303 6-14-68 200.341 (S)		3051-D07-1A-304 6-18-68 200.843 (S)		3051-D07-1A-305 6-24-68 200.746 (S)		3051-D07-1A-306 7-26-68 200.746 (S)		3051-D07-1A-307 8-1-68 200.470 (S)	
2	1	2	1	2	1	2	1	2	1	2
333	662	333	662	333	659	666	659	666	659	666
759	001	759	001	759	001	759	001	759	001	759
807	896	807	896	807	896	807	896	807	896	807
048	047	048	047	048	047	048	047	048	047	048
390	388	390	388	390	388	390	388	390	388	390
165	164	165	164	165	164	165	164	165	164	165
055	051	055	051	055	051	055	051	055	051	055
---	---	---	---	---	---	---	---	---	006	005

00.990 sec (this is total time prior to engine testing).

.140 sec (this is total time prior to engine testing).

/2 cycles.

/1 cycle.

s no prior usage.

s no prior usage.

prior usage.

prior usage.

cluding tests shown in note (3), due to a full load

cluding tests shown in note (4), due to a full load

.

or further tests. Time on seal 1544.011 sec/10 cycles.

or further tests. Time on seal 1448.611 sec/9 cycles.

was 1246.181 sec/8 cycles. Installed SN 641.

of thrust chamber valves on SA-1 to open. For time
me/cycles than the rest of the engine.

nd have no prior usage.

fer to IR-469284.

fer to IR-469285.

2

Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine S

				Test	3051-D07-1A-308		3051-D07-1A-309		3051
				Date	8-14-68		8-15-68		
				Dur.	20.977		2.569		
Part Number	Name	Name	SN	SA	1	2	1	2	1
260825-11	Second Stage Nozzle	TPA	009/011	SN	659	666	659	666	65
1154950-1	First Stage Rotor		009/011	Fired	001	759	001	759	00
1130974-3	Second Stage Rotor		009/011		896	807	896	807	89
1122654-59	Turbine Manifold		009/011		047	048	047	048	04
1131351-59	Gearbox Assembly		009/011		388	390	388	390	38
1130728-3	Lube Oil Cooler		009/011		164	165	164	165	16
1130976-29	Turbine Rotor Bolt		009/011		051	055	051	055	05
1155001-1	Exit Closure	TCA	477/478		---	---	---	---	--

og, Engine S/N 15 (cont.)

A-309	3051-D07-1A-310		3051-D07-1A-311		3051-D07-1A-312		3051-D07-1A-313		3051-D07-1A-314	
8	8-16-68		9-17-68		9-19-68		9-28-68		10-1-68	
	200.361		21.340		201.114 (S)		20.845 (N2)		200.908 (S)	
2	1	2	1	2	1	2	1	2	1	2
666	659	666	743(17)	746(17)	743	746	743	746	743	746
759	001	759	783(18)	788(18)	783	788	783	788	783	788
807	896	807	896	807	896	807	896	807	896	807
048	047	048	047	048	047	048	047	048	047	048
390	388(19)	390(20)	388	390	388	390	388	390	388	390
165	164	165	164	165	164	165	164	165	164	165
055	051	055	051	055	051	055	051	055	051	055
---	---	---	---	---	---	---	---	---	---	---

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Table II -- Titan IIIM Stage I Engine Time-Cycle Log, Engine

		Top Assembly		Test	3051-D07-1A-315		3051-D07-1A-316	
				Date	10-3-68		10-17-68	
				Dur.	21.095 (N2)		200.809 (S)	
Part Number	Name	Name	SN	SA	1	2	1	2
260825-11	2nd Stage Nozzle	TPA	009/011	SN	743	746	743	746
1154950-1	1st Stage Rotor		009/011	Fired	783	788	783	788
1130974-3	2nd Stage Rotor		009/011		896	807	896	807
1122654-59	Turbine Manifold		009/011		047	048	047	048
1131351-59	Gearbox Assy		009/011		388	390	388	390
1130728-3	Lube Oil Cooler		009/011		164	165	164	165
1130976-29	Turbine Rotor Bolt		009/011		051	055	051	055
1155001-1	Exit Closure	TCA	477/478		---	---	007	008

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itan IIIM Stage I Engine Time-Cycle Log, Engine S/N 15 (cont.)

Test	3051-D07-1A-315		3051-D07-1A-316											
Date	10-3-68		10-17-68											
Dur.	21.095 (N2)		200.809 (S)											
SA	1	2	1	2	1	2	1	2	1	2	1	2	1	2
SN Fired	743	746	743	746										
	783	788	783	788										
	896	807	896	807										
	047	048	047	048										
	388	390	388	390										
	164	165	164	165										
	051	055	051	055										
	---	---	007	008										

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Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 14

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1129200	-9	Rocket Engine	438435	12-21-67	Post 201	19.657/1
1129200	-9	Rocket Engine	438473	2-14-68	Post 203	421.067/3
284899	-19	Hot Gas Cooler SN 753	438487	3-12-68	Post 204	536.505/4
1129200	-9	Rocket Engine	438607	4-3-68	Post 204	536.505/4
1129200	-9	Rocket Engine	438609	4-8-68	Post 205	557.356/[illegible]

e III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 14

r	Date	Pre/Post 3051-D07-LA	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
5	12-21-67	Post 201	19.657/1	E.T.S. shutdown due to loss of deflector plate water pressure.	X		
3	2-14-68	Post 203	421.067/3	Fuel and oxidizer discharge line bellows tripod measurement found below min (SA-1 and SA-2).	X		Insp.
7	3-12-68	Post 204	536.505/4	Internal leakage noted during post test leak check.		X	
7	4-3-68	Post 204	536.505/4	Fuel and oxidizer discharge line bellows tripod measurement found below min (SA-1 and SA-2).	X		Insp.
9	4-8-68	Post 205	557.356/5	Fuel and oxidizer discharge line bellows tripod measurement found below min (SA-1 and SA-2).	X		Insp.

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Table III--Time History of Discrepant Hardware (co

Engine Model LR87-AJ-11, Serial No. 14 (cont.

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1129200	-9	Rocket Engine	438613 438645	4-16-68	Post 206	758.281/6
261285	-39	Fluid Heater SN 378	276717	4-11-68	Post 206	758.281/6
1129200	-9	Rocket Engine	458749 (Item 34)	7-2-68	Post 209	1000.670/9

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
438613 438645	4-16-68	Post 206	758.281/6	(1) Steady state TTi on SA-1 was 1708°F. Max allowed is 1700°F.	X		Insp.
				(2) Fuel and oxidizer discharge line bellows tripod measurement found below min (SA-1 and SA-2)	X		Insp.
278717	4-11-68	Post 206	758.281/6	Fluid heater was soaked in Turco solution for 45 min. ATP-TDO B5150, Item 2.2 authorizes 30 ± 5 minutes.	X		
458749 (Item 34)	7-2-68	Post 209	1000.670/9	Discharge line bellows tripod measurement found below min (SA-1 and SA-2 oxid. and SA-2 fuel).	X		Insp.

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Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 14 (c

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1129200	-9	Rocket Engine	458749 (Item 39)	7-8-68	Post 210	1200.985.1
1129200	-9	Rocket Engine	458749 (Item 47)	7-11-68	Post 211	1221.729/1
1129200	-9	Rocket Engine	468425 (Item 4)	7-15-68	Post 212	1422.735/2
1129200	-9	Rocket Engine	458749 (Item 64)	7-17-68	Post 213	1443.497/1

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e III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

r	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
9)	7-8-68	Post 210	1200.985.10	Discharge line bellows tripod measurement found below min (SA-1 and SA-2 oxid. and SA-2 fuel).	X		Insp.
7)	7-11-68	Post 211	1221.729/11	SA-1 and SA-2 oxid discharge line bellows tripod measurement found below min.	X		Insp.
)	7-15-68	Post 212	1422.735/2	Post test data review showed SA-1 and SA-2 TTI exceed 1700°F during steady state. This condition due to high propellant temperature.	X		Insp.
4)	7-17-68	Post 213	1443.497/13	Discharge line bellows tripod measurement found below min (SA-1 and SA-2 oxid. and SA-2 fue').	X		Insp.

2

Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 14 (co

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
294251		Oxidizer Suction Line SN 624	469108	8-1-68	Post 214	1644.510/1
294251		Oxidizer Suction Line SN 625	469115	8-6-68	Post 214	1644.510/1
294251		Oxidizer Suction Line SN 624	458749 (Item 103)	8-27-68	Post 215	1844.968/1
294251		Oxidizer Suction Line SN 628	458749 (Item 103)	8-27-68	Post 215	200.458/1
				Turbopump Assy SN 006		
1129464	-11	Gearbox Temp. Thermocouple	438606	4-3-68	Pre 205	0/0
260825	-11	Second Stage Nozzle SN 596	E.T.R.S. No. 50	7-8-68	Post 210	866.670/1

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
69108	8-1-68	Post 214	1644 510/14	Distorted approximately 1/2 in. on bottom convolutions.	X		Insp.
69115	8-6-68	Post 214	1644.510/14	Distorted approximately 0.575 on top convolutions and approximately 0.450 on bottom convolutions.		X	Reject
58749 em 103)	8-27-68	Post 215	1844.968/15	Bellows distorted.	X		
58749 em 103)	8-27-68	Post 215	200.458/1	Bellows distorted.		X	Reject
	Turbopump Assy SN 006						
38606	4-3-68	Pre 205	0/0	End of pipe plug was broken during thermocouple installation.	X		Rework Post 205
E.T.R.S. No. 50	7-8-68	Post 210	866.670/7	Replaced per engineering request.		X	

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Table III--Time History of Discrepant Hardware (c

Engine Model LR87-AJ-11, Serial No. 14 (cont

Turbopump Assy SN 008

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1130983	-1	First Stage Rotor SN 164	438439	12-28-67	Post 201	219.657/2
1130120	-3	Second Stage Rotor SN 799	438439	12-28-67	Post 201	219.657/2
1130976	-29	Turbine Rotor Bolt SN 055	438439	12-28-67	Post 201	219.657/2
1130983	-1	First Stage Rotor SN 622	443894	1-3-68	Post 202	200.825/1
1130983	-1	First Stage Rotor SN 622	457365	1-11-68	Post 203	601.420/3
1130974	-1	Second Stage Rotor SN 002	E.T.R.S.	1-11-68	Post 203	601.420/3
1132400	-9	Turbine GB Seal SN 4741	438497	3-26-68	Post 204	936.505/6

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ble III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Turbopump Assy SN 008

R ber	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
439	12-28-67	Post 201	219.657/2	Rotor not to configuration.		X	
439	12-28-67	Post 201	219.657/2	Rotor not to configuration.		X	
439	12-28-67	Post 201	219 657/2	No evidence of inspection.		X	
394	1-3-68	Post 202	200.825/1	Numerous cracks in blades.	X		
365	1-11-68	Post 203	601.420/3	Cracks in blades. Note: An accept disposition contested by Aerospace.		X	
R.S.	1-11-68	Post 203	601.420/3	Replaced per engineering request.		X	
497	3-26-68	Post 204	936.505/6	Gap between running ring and 1st stage rotor is 0.006 min. Allowed per BIP is 0.010.			X

Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 14 (co

Turbopump Assy SN 008 (cont.)

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1131352	-139	Turbopump Assy SN 008	463599	5-18-68	Post 208	1180.095/
260825	-11	Second Stage Nozzle SN 665	E.T.R.S. No. 50	7-8-68	Post 210	664.480/
1132400	-9	Turbine GB Seal SN 4793	468425 (Item 5)	7-15-68	Post 212	442.640/
291377	-19	Oxidizer Pump Seal SN 1349	469104	7-31-68	Post 214	1344.510/
				Turbopump Assy SN 010		
1130119	-1	First Stage Rotor SN 607	438439	12-28-67	Post 201	219.737/
1130120	-3	Second Stage Rotor SN 797	438439	12-28-67	Post 201	219.737/

Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Turbopump Assy SN 008 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
463599	5-18-68	Post 208	1180.095/8	(1) Keenserts in GB to turbine man. flange are below flange surface.			X
				(2) 4 helicoils for oil baffle brackets are not self locking.			X
E.T.R.S. No. 50	7-8-68	Post 210	664.480/6	Replaced per engineering request.		X	
468425 (Item 5)	7-15-68	Post 212	442.640/4	Seal leaked 1100 cc/min. max. Allowable is 750 cc/min.	X		
469104	7-31-68	Post 214	1844.510/15	Seal leaked 1400 cc/min. max. Allowable is 900 cc/min.	X		
		Turbopump Assy SN 010					
438439	12-28-67	Post 201	219.737/2	Rotor not to configuration.		X	
438439	12-28-67	Post 201	219.737/2	Rotor not to configuration.		X	

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Table III--Time History of Discrepant Hardware (c

Engine Model LR87-AJ-11, Serial No. 14 (cont

Turbopump Assy SN 010 (cont.)

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1130976	-29	Turbine Rotor Bolt SN 060	438439	12-28-67	Post 201	219.737/2
1130983	-1	First Stage Rotor SN 624	443895	1-3-68	Post 202	200.825/1
1130974	-1	Second Stage Rotor SN 003	E.T.R.S.	1-3-68	Post 202	200.825/1
1131352	-69	Turbopump Assy SN 010	438450	1-11-68	Post 203	621.147/4
1130976	-29	Turbine Rotor Bolt SN 061	438452	1-11-68	Post 203	401.410/2
1130728	-3	Lube Oil Cooler SN 013	458409	1-17-68	Post 203	621.147/4
1130983	-1	First Stage Rotor SN 638	457310	1-15-68	Post 203	400.705/2
1130983	-1	First Stage Rotor SN 638	461242	3-14-68	Post 204	516.143/3
1131352	-69	Turbopump assy SN 010	438486	3-11-68	Post 204	736.585/5

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Turbopump Assy SN 010 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Disposition Replace	Disposition Rework
438439	12-28-67	Post 201	219.737/2	No evidence of inspection.		X	
443895	1-3-68	Post 202	200.825/1	Crack in fir tree No. 42 and cracks in blades.		X	
E.T.R.S.	1-3-68	Post 202	200.825/1	Replaced per engineering request.		X	
438450	1-11-68	Post 203	621.147/4	Excessive lube oil on rotors.	X		
438452	1-11-68	Post 203	401.410/2	Rotor bolt found to be finger tight.	X		Insp.
458409	1-17-68	Post 203	621.147/4	Dent in cooler 0.500 long x 0.030 deep.		X	
457310	1-15-68	Post 203	400.705/2	Cracks in blades.	X		
461242	3-14-68	Post 204	516.143/3	All buckets removed during test.		X	
438486	3-11-68	Post 204	736.585/5	Premature shutdown at 115.438 sec. TPA could not be rotated at 20 ft/lb.		X	

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Table III--Time History of Discrepant Hardwa

Engine Model LR87-AJ-11, Serial No. 14 (

Turbopump Assy SN 010 (cont.)

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Tim Cycl
1122654	-59	Turbine Manifold SN 041	461243	3-14-68	Post 204	736.58
260825	-11	Second Stage Nozzle SN 660	461244	3-14-68	Post 204	736.58
1130974	-1	Second Stage Rotor SN 008	461245	3-14-68	Post 204	516.14
				Thrust Chamber Assy SN 475		
1131736	-9	PSV SN 6.3	463597	5-28-68	Post 208	980.09
1133735	-3	Ablative Skirt SN 003	468440	7-23-68	Post 214	201.01
1130063	-19	TCOV SN 606	469252	8-6-68	Post 214	1644.51
1154627	-9	Ablative Skirt SN 032	468483	8-28-68	Post 215	200.4

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ble III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Turbopump Assy SN 010 (cont.)

R ber	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
243	3-14-68	Post 204	736.585/5	All directional vanes damaged beyond post fire limits of AGC 46610.		X	
244	3-14-68	Post 204	736.585/5	All directional vanes damaged beyond post fire limits of AGC 46610.		X	
245	3-14-68	Post 204	516.143/3	All buckets damaged beyond post fire limits of AGC 46610.		X	
		Thrust Chamber Assy SN 475					
597	5-28-68	Post 208	980.095/8	PSV failed dielectric test			Replaced PSVOR
440	7-23-68	Post 214	201.013/1	Skirt damaged during test.		Scrap	
9252	8-6-68	Post 214	1644.510/14	Minor scratches and corrosion throughout valve.			X
483	8-28-68	Post 215	200.458/1	Sealant ring on inside top has erosion 22-3/4 in. from datum line.		Scrap	

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Table III --Time History of Discrepant Hardware (cont

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Combustion Chamber History, PN 1130174-79, SN 0

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/m Tube-Flange	Tube
204	3-11-68	115.438	2	Yes	115.438/1	0.020	0.020	-	-
205	4-4-68	20.851	2	No	136.289/2	0.011	0.025	-	-
206	4-10-68	200.925	2	Yes	337.214/3	0.020	0.022	-	-
207	4-29-68	200.599	1	No	537.813/4	0.003	0.031	-	-
208	5-4-68	21.215	1	No	559.028/5	0.015	0.030	-	-
209	7-1-68	20.575	1	No	579.603/6	0.014	0.016	-	-
210	7-5-68	200.135	1	No	779.918/7	0.035	0.032	-	-
211	7-10-68	20.744	1	No	800.662/8	0.032	0.022	-	-
212	7-12-68	201.006	1	No	1001.668/9	0.035	0.032	-	*
213	7-16-68	20.762	1	No	1022.430/10	0.035	0.030	-	*
214	7-22-68	201.013	1	Yes	1223.443/11	0.035	0.035	-	*
215	8-27-68	200.458	1	Yes	1423.90/12	0.032	0.030	-	*

III --Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 14 (cont.)
ombustion Chamber History, PN 1130174-79, SN 017

Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Other	Repairs/Remarks
115.438/1	0.020	0.020	-	-	-	C.C. SN 017 has had numerous repairs prior to use on SN 14 Engine (IR 448857).
136.289/2	0.011	0.025	-	-	-	
337.214/3	0.020	0.022	-	-	-	
537.813/4	0.003	0.031	-	-	-	
559.028/5	0.015	0.030	-	-	-	IR 463721
579.603/6	0.014	0.016	-	-	-	IR 468408
779.918/7	0.035	0.032	-	-	-	IR 458749 (Item 37)
800.662/8	0.032	0.022	-	-	-	Erosion noted at flange 2 in. above where tube No. 64 joins CC flange. Erosion is within damage limits (IR 468417 and 468419).
001.668/9	0.035	0.032	-	*	-	*Seeping thru cracks in crown of tube No. 64 1 in. below chamber flange (IR 468425 and 458749).
022.430/10	0.035	0.030	-	*	-	*Seeping thru cracks in crown of tube No. 64 1 in. below chamber flange (IR 458749).
223.443/11	0.035	0.035	-	*	-	Slightly worse than test No. 212 (Tube No. 64).
423.90/12	0.032	0.030	-	*	-	*Same as Test No. 214 (IR 458749).

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Table III --Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Combustion Chamber History, PN 1133311-19, SN 092

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Ot
209	7-1-68	20.575	2	No	20.575/1	0.030	0.011	-	-	
210	7-5-68	200.315	2	No	220.890/2	0.015	0.014	-	-	
211	7-10-68	20.744	2	No	241.634/3	0.016	0.015	-	-	
212	7-12-68	201.006	2	No	442.640/4	0.018	0.015	-	-	
213	7-16-68	20.762	2	No	463.402/5	0.019	0.016	-	-	
214	7-22-68	201.013	2	Yes	664.415/6	*	0.020	-	-	
215	8-27-68	200.458	2	Yes	864.873/7	*	0.022	-	-	

* Note: Gap measurements not available but assumed to be in spec since no IR's written against engine.

Table III --Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 14 (cont.)
Combustion Chamber History, PN 1133311-19, SN 092

rt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Other	Repairs/Remarks
	20.575/1	0.030	0.011	-	-	-	First test on this chamber.
	220.890/2	0.015	0.014	-	-	-	
	241.634/3	0.016	0.015	-	-	-	
	442.640/4	0.018	0.015	-	-	-	
	463.402/5	0.019	0.016	-	-	-	
s	664.415/6	*	0.020	-	-	-	
s	864.873/7	*	0.022	-	-	-	3 in. cracks in weld joint at shell to aft wire lock ring (IR 458749).

assumed to be in spec since no IR's written

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Table III --Time History of Discrepant Hardware (

Engine Model LR87-AJ-11, Serial No. 14 (con

Injector History, PN 1130409-129, SN 697

Test	Date	Duration	S/A	Skirt	Accum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7
201	12-20-67	19.657	1	No	140.757/3	-	-	-	-	-	-	-
202	12-29-67	200.825	1	No	341.582/4	-	-	-	-	-	-	-
203	1-10-68	200.585	1	No	542.167/5	-	-	-	-	-	-	-
204	3-11-68	115.438	1	Yes	657.605/6	3	2	1	2	2	3	4
205	4-4-68	20.851	1	No	678.456/7	-	-	-	-	-	-	-
206	4-10-68	200.925	1	Yes	879.381/8	-	-	1	1	1	1	-
207	4-29-68	200.599	1	No	1079.980/9	-	-	1	1	1	-	-
208	5-4-68	21.215	1	No	1101.195/10	1	-	-	-	1	-	1
209	7-1-68	20.575	1	No	1121.770/11	-	-	-	-	-	-	-
210	7-5-68	200.315	1	No	1322.085/12	-	-	-	-	-	-	-
211	7-10-68	20.744	1	No	1342.829/13	-	-	-	-	-	-	-
212	7-12-68	201.006	1	No	1543.835/14	-	-	-	-	2	-	-
213	7-16-68	20.762	1	No	1564.597/15	-	-	-	-	2	-	-
214	7-22-68	201.013	1	Yes	1765.610/16	2	1	-	-	1*	-	-
215	8-27-68	200.458	1	Yes	1966.068/17	2	2	-	-	-	-	-

--Time History of Discrepant Hardware (cont.)
ne Model LR87-AJ-11, Serial No. 14 (cont.)
jector History, PN 1130409-129, SN 697

um. C	Baffle Weld Cracks 1	2	3	4	5	6	7	Repairs/Remarks
757/3	-	-	-	-	-	-	-	
582/4	-	-	-	-	-	-	-	
167/5	-	-	-	-	-	-	-	
605/6	3	2	1	2	2	3	4	IR 438489
456/7	-	-	-	-	-	-	-	Injector repaired before this test (baffle to face fillet welds). No damage post 205.
381/8	-	-	1	1	1	1	-	Baffle cracks repaired for this test (IR 438611).
980/9	-	-	1	1	1	-	-	New cracks appeared this test (IR 438647).
195/10	1	-	-	-	1	-	1	
770/11	-	-	-	-	-	-	-	Weld crack repaired before this test. No new cracks.
.085/12	-	-	-	-	-	-	-	
.829/13	-	-	-	-	-	-	-	
.835/14	-	-	-	-	2	-	-	IR 468425
.597/15	-	-	-	-	2	-	-	
.610/16	2	1	-	-	1*	-	-	*2 previous short cracks are now 1 long crack (IR 469106).
.068/17	2	2	-	-	-	-	-	Baffle weld cracks repaired prior to this test (cracks shown are new).

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Table III--Time History of Discrepant Hardware (c

Engine Model LR87-AJ-11, Serial No. 14 (cont

Thrust Chamber Assy SN 476

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1131273	-9	Thrust Chamber Assy SN 476	458749 (Item 36)	7-5-68	Post 209	1000.670/9
1133735	-3	Ablative Skirt SN 005	468439	7-23-68	Post 214	201.013/1
1130063	-19	TCOV SN 604	469421	8-2-68	Post 214	1644.510/1

Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Thrust Chamber Assy SN 476

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Disposition Replace	Disposition Rework
458749 (Item 36)	7-5-68	Post 209	1000.670/9	TCA had fuzz leakage at 5 and 10 o'clock starting CW from fuel inlet between CC and injector.			X
468439	7-23-68	Post 214	201.013/1	Skirt damaged during test.		Scrap	
469421	8-2-68	Post 214	1644.510/14	Minor scratches and corrosion throughout valve.			X

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Table III --Time History of Discrepant Hardware (co

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Combustion Chamber History, PN 1130174-79, SN 0

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/m Tube-Flange	Tube
201	12-20-67	19.657	1	No	19.657/1	0.000	0.012	-	-
202	12-29-67	200.825	1	No	220.482/2	0.012	0.015	-	-
203	1-10-68	200.585	1	No	421.067/3	0.011	0.010	-	-
204	3-11-68	115.438	1	Yes	536.505/4	0.007	0.016	-	-
205	4-4-68	20.851	1	No	557.356/5	0.010	0.016	-	-
206	4-10-68	200.925	1	Yes	758.281/6	0.018	0.020	-	-
207	4-29-68	200.599	2	No	958.880/7	0.016	0.018	*	-
208	5-4-68	21.215	2	No	980.095/8	0.012	0.015	24.0	-

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LI --Time History of Discrepant Hardware (cont.)
gine Model LR87-AJ-11, Serial No. 14 (cont.)
ustion Chamber History, PN 1130174-79, SN 019

ccum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Other	Repairs/Remarks
19.657/1	0.000	0.012	-	-	-	
20.482/2	0.012	0.015	-	-	-	
21.067/3	0.011	0.010	-	-	-	
36.505/4	0.007	0.016	-	-	-	
57.356/5	0.010	0.016	-	-	-	
58.281/6	0.018	0.020	-	-	-	
58.880/7	0.016	0.018	*	-	-	*Wetness noted, possibly coming from forward flange and flowing down between tubes (IR 438648).
80.095/8	0.012	0.015	24.0	-	-	Chamber removed after this test because of excessive leakage (IR 458749 and 463765).

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Table III --Time History of Discrepant Hardware (cont

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Combustion Chamber History, PN 1130174-79, SN 02(

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/mi Tube-Flange	Tube
201	12-20-67	19.657	2	No	19.657/1	0.001	0.006	-	-
202	12-29-67	200.825	2	No	220.482/2	0.015	0.015	-	-
203	1-10-68	200.585	2	No	421.067/3	0.010	0.015	-	-

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Table III --Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 14 (cont.)
Combustion Chamber History, PN 1130174-79, SN 020

		Inj-CC-Gap (max)		Leakage (cc/min)			
rt	Accum. T/C	Pre	Post	Tube-Flange	Tube	Other	Repairs/Remarks
b	19.657/1	0.001	0.006	-	-	-	
b	220.482/2	0.015	0.015	-	-	-	Epon cracks and loose wire wrap noted on post -201. O.K. for next test (IR 438436 and 438440).
b	421.067/3	0.010	0.015	-	-	-	Two cracks in forward flange in line with tubes 44 and 108. Cracks are located approximately 1/2 in. from base of flange and extend upward 1/2 in. Tube 64 is cracked starting 1 in. down stream of flange and extending 1-3/4 in. down stream. This CC removed from Engine and SN 017 was installed for test No. 204 (IR's 438453, 45[illegible]91 and 457254).

Table III --Time History of Discrepant Hardware (cont

Engine Model LR87-AJ-11, Serial No. 14 (cont.)

Injector History, PN 11304-09-129, SN 696

Test	Date	Duration	S/A	Skirt	Accum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7	
201 202	12-20-67	19.657	2	No	140.757/3	-	-	-	-	-	-	-	
202	12-29-67	200.825	2	No	341.528/4	-	-	-	-	-	-	-	
203	1-10-68	200.585	2	No	542.167/5	-	-	-	-	-	-	-	
204	3-11-66	115.438	2	Yes	657.605/6	2	-	-	2	2	-	2	IR
205	4-4-68	20.851	2	No	678.456/7	-	-	-	-	-	-	-	In tc
206	4-10-68	200.925	2	Yes	879.381/8	-	1	1	-	1	1	-	Ba (1
207	4-29-68	200.599	2	No	1079.980/9	-	-	1	-	2	-	-	Ne
208	5-4-68	21.215	2	No	1101.195/10	1	-	1	-	3	-	1	Ba
209	7-1-68	20.575	2	No	1121.770/11	-	-	-	-	-	-	-	Ir cl
210	7-5-68	200.315	2	No	1322.085/12	-	-	-	-	-	-	-	
211	7-10-68	20.744	2	No	1342.829/13	-	-	-	-	-	-	-	
212	7-12-68	201.006	2	No	1543.835/14	1	-	-	1	-	-	-	Il
213	7-16-68	20.762	2	No	1564.597/15	1	-	-	1	-	-	-	
214	7-22-68	201.013	2	Yes	1765.610/16	1	-	-	1	1	-	-	I
215	8-27-68	200.458	2	Yes	1966.068/17	1	1	-	1	1	1	-	

I--Time History of Discrepant Hardware (cont.)
ine Model LR87-AJ-11, Serial No. 14 (cont.)
njector History, PN 11304-09-129, SN 696

cum.	Baffle Weld Cracks							
/C	1	2	3	4	5	6	7	Repairs/Remarks
.757/3	-	-	-	-	-	-	-	
.528/4	-	-	-	-	-	-	-	
.167/5	-	-	-	-	-	-	-	
.605/6	2	-	-	2	2	-	2	IR 438492
.456/7	-	-	-	-	-	-	-	Injector repaired before this test. (Baffle to face fillet welds.) No new damage post 205.
.381/8	-	1	1	-	1	1	-	Baffle cracks repaired after this test (IR 438612).
.980/9	-	-	1	-	2	-	-	New cracks appeared this test (IR 438646).
.195/10	1	-	1	-	3	-	1	Baffle No. 3 replaced after this test (IR 458749).
.770/11	-	-	-	-	-	-	-	Injector repaired before this test. No new cracks.
2.085/12	-	-	-	-	-	-	-	
2.829/13	-	-	-	-	-	-	-	
3.835/14	1	-	-	1	-	-	-	IR 468425
4.597/15	1	-	-	1	-	-	-	
5.610/16	1	-	-	1	1	-	-	IR 469107
6.068/17	1	1	-	1	1	1	-	

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Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 15

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
1129200	-19	Rocket Engine	468474	8-15-68	Post 309	1248.268/9
				GGA SN 491		
259387		Fuel Bootstrap Line SN 542	438693	6-19-68	Post 304	622.861/4
702642	-59	GGOCKV SN 870	468117	10-4-68	Post 315	1913.931/1
				TCA SN 477		
1154627	-9	Ablative Skirt SN 035	458748 (Item 32)	6-24-68	Post 305	200.645/1
1131736	-9	PSV SN 640	469270	8-16-68	Post 309	1245 699/

Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15

IR umber	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
68474	8-15-68	Post 309	1248.268/9	Premature shutdown at FS_1 + 2.569 sec			X
	GGA SN 491						
38693	6-19-68	Post 304	622.861/4	Postfire leak check revealed leakage through braid in two places.		X	
68117	10-4-68	Post 315	1913.931/15	Reverse flow leak check with TOJ thermocouple removed revealed reverse leakage of 12,000 cc/min. Valve bench checked with no leakage and reinstalled.	X		Insp.
	TCA SN 477						
58748 tem 32)	6-24-68	Post 305	200.645/1	Liner dented approximately 8-in. ccw from part tag and 3-in. from bottom ring.		X	
69270	8-16-68	Post 309	1245.699/8	Override solenoid did not operate resulting in premature shutdown.		X	

Table I[illegible]--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 15 (co

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
				TCA SN 477 (cont.)		
299093		PSV Override Solenoid SN 2437	457344	8-16-68	Post 309	1245.699/8
				TCA SN 478		
1129770	-19	Ablative Skirt SN 038	458748 (Item 33)	6-24-68	Post 305	200.645/1
1129770	-19	Ablative Skirt SN 021	458748 (Item 55)	8-1-68	Post 307	200.470/1
1131736	-9	PSV SN 642	469136	8-28-68	Post 310	1448.629/1

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-Time History of Discrepant Hardware (cont.)

e Model LR87-AJ-11, Serial No. 15 (cont.)

Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
TCA SN 477 (cont.)						
8-16-68	Post 309	1245.699/8	Bench tests, conducted as a result of failure during Test -309, revealed that the override solenoid actuated on the first try and failed on the second and third tries with 26 v applied.		X	
TCA SN 478						
6-24-68	Post 305	200.645/1	Liner dented approximately 5 in. up from bottom ring and 10 in. ccw from part tag.		X	
8-1-68	Post 307	200.470/1	Skirt eroded at top inside of mating flange.		X	
8-28-68	Post 310	1448.629/10	Removed in accordance with engineering request and reinstalled.	X		Insp.

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Table III--Time History of Discrepant Hardware (

Engine Model LR87-AJ-11, Serial No. 15 (con

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
				TCA SN 478 (cont.)		
299093		PSV Override Solenoid SN 2430	468815	9-9-68	Post 310	1448.629/1(
				TPA SN 009		
1129464	-11	Gearbox Temp Probe SN 7N1219	438672	6-3-68	Pre 301	0/0
260825	-11	Second Stage Nozzle SN 662	ETRS No. 45	6-19-68	Post 304	920.691/6
291377	-19	Oxidizer Pump Seal SN 1350	468456	8-12-68	Post 307	1522.552/9
291377	-19	Oxidizer Pump Seal SN 1350	468468	8-14-68	Post 308	1543.529/1
291377	-19	Oxidizer Pump Seal SN 1350	---	8-15-68	Post 309	1546.098/1

Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Disposition Replace	Disposition Rework
	TCA SN 478 (cont.)						
468815	9-9-68	Post 310	1448.629/10	Replaced in accordance with engineering request.		X	
	TPA SN 009						
438672	6-3-68	Pre 301	0/0	TB-5 thermocouple will not fit properly into gearbox.	X		
ETRS No. 45	6-19-68	Post 304	920.691/6	Replace per engineering request.		X	
468456	8-12-68	Post 307	1522.552/9	Posttest leak check revealed leakage too great to measure.	X		
468468	8-14-68	Post 308	1543.529/10	Leaks too great to measure.	X		
---	8-15-68	Post 309	1546.098/11	Leak checks not performed due to premature shutdown.			

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Table III--Time History of Discrepant Hardware

Engine Model LR87-AJ-11, Serial No. 15 (cc

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
				TPA SN 009 (cont.)		
291377	-19	Oxidizer Pump Seal SN 1350	469293	8-29-68	Post 310	1746.45[illegible]/
1131352	-139	TPA SN 009	458748 (Item 74)	8-17-68	Post 310	1746.459/
1154950	-1	First Stage Rotor SN 001	469284	8-29-68	Post 310	1649.619/
260825	-11	Second Stage Nozzle SN 659	469284	8-29-68	Post 310	825.768/
291378	-19	Fuel Pump Seal SN 1353	476538	11-12-68	Post 316	2412.570/
				TPA SN 011		
1129464	-11	Gearbox Temp Probe SN 7N1229	438672	6-3-68	Pre 301	0/0

ıı--Time History of Discrepant Hardware (cont.)

ngine Model LR87-AJ-11, Serial No. 15 (cont.)

Date	Pre/Post 3051-P07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Disposition Replace	Disposition Rework
TPA SN 009 (cont.)						
8-29-68	Post 310	1746.459/12	Gross leakage noted through seal.		X	
8-17-68	Post 310	1746.459/12	Posttest data review revealed TTI exceeded 1700°F during steady state.	X		Insp.
8-29-68	Post 310	1649.619/11	Replaced in accordance with engineering request.		X	
8-29-68	Post 310	825.768/6	Replaced per engineering request.		X	
11-12-68	Post 316	2412.570/18	Bellows in seal assembly is cracked and leaks excessively.		X	
TPA SN 011						
6-3-68	Pre 301	0/0	TB-5 thermocouple will not fit properly into gearbox.	X		

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Table III--Time History of Discrepant Hardware (

Engine Model LR87-AJ-11, Serial No. 15 (con

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
				TPA SN 011 (cont.)		
1133478	-1	NT Probe SN 764	438681	6-13-6	Post 302	221.677/2
260825	-11	Second Stage Nozzle SN 333	ETRS No. 45	6-19-68	Post 304	825.291/5
1132400	-19	Turbine Seal SN 4869	468402	6-26-68	Post 305	823.506/5
1132400	-19	Turbine Seal SN 4869	468111 (Item 3)	10-2-68	Post 314	1892.836/1
291377	-19	Oxidizer Pump Seal SN 1348	468456	8-12-68	Post 307	1427.152/8
291377	-19	Oxidizer Pump Seal SN 1348	468468	8-14-68	Post 308	1448.129/9

Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
	TPA SN 011 (cont.)						
438681	6-13-68	Post 302	221.677/2	Posttest check revealed NT probe electrical circuit to be open.		X	
ETRS No. 45	6-19-68	Post 304	825.291/5	Replaced per engineering request.		X	
468402	6-26-68	Post 305	823.506/5	Posttest leak check revealed 1200 cc/min leakage. Maximum allowable leakage is 750 cc/min.			X
468111 (Item 3)	10-2-68	Post 314	1892.836/14	Posttest leak check revealed 2000 cc/min leakage. Maximum allowable leakage is 750 cc/min.	X		
468456	8-12-68	Post 307	1427.152/8	Posttest leak check revealed leakage too great to measure.	X		
468468	8-14-68	Post 308	1448.129/9	Leaks too great to measure.	X		

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Table III--Time History of Discrepant Hardware (

Engine Model LR87-AJ-11, Serial No. 15 (co

Part Number	Configuration	Nomenclature	IR Number	Date	Pre/Post 3051-D07-1A	Time/ Cycles
				TPA SN 011 (cont.)		
291377	-19	Oxidizer Pump Seal SN 1348	--	8-15-68	Post 309	1450.698/1
291377	-19	Oxidizer Pump Seal SN 1348	469290	8-29-68	Post 310	1651.059/1
1131352	-139	TPA SN 011	458748 (Item 74)	8-17-68	Post 310	1651.059/1
1154950	-1	First Stage Rotor SN 759	469285	8-29-68	Post 310	1458.769/
260825	-11	Second Stage Nozzle SN 666	469285	8-29-68	Post 310	825.768/

ble III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

R ber	Date	Pre/Post 3051-D07-1A	Time/ Cycles	Brief Description of Discrepancy	Disposition Accept	Replace	Rework
	TPA SN 011 (cont.)						
-	8-15-68	Post 309	1450.698/10	Leak checks not performed due to premature shutdown.			
290	8-29-68	Post 310	1651.059/11	Gross leakage noted through seal.		X	
748 m 74)	8-17-68	Post 310	1651.059/11	Posttest data review revealed TTI exceeded 1700°F during steady state.	X		Insp.
285	8-29-68	Post 310	1458.769/11	Replaced in accordance with engineering request.		X	
285	8-29-68	Post 310	825.768/6	Replaced in accordance with engineering request.		X	

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Table III --Time History of Discrepant Hardware (cont.

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Combustion Chamber History, PN 1133311-19, SN 021

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min Tube-Flange	Tube	C
					Thrust Chamber Assy SN 477					
301	6-3-68	20.669	1	No	20.669/1	0.015	0.010	-	-	
302	6-6-68	201.008	1	No	221.677/2	0.011	0.015	-	-	
303	6-14-68	200.341	1	No	422.018/3	0.019	0.018	-	-	
304	6-18-68	200.843	1	No	622.861/4	0.019	0.019	-	-	
305	6-24-68	200.645	1	Yes	823.506/5	**	0.016	*	-	
306	7-26-68	200.746	1	No	1024.252/6	0.012	0.018	*	-	
307	8-1-68	200.470	1	Yes	1224.722/7	0.018	0.018	*	-	
308	8-14-68	20.977	1	No	1245.699/8	**	0.018	*	-	
309	8-15-68	0.0	1	No	1245.699/8	**	**	*	-	
310	8-16-68	200.361	1	No	1446.060/9	**	0.015	2.0	-	

** Notes: Gap measurements not available but assumed to be in specification since there are no IRs written against engine.

Table III--Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 15 (cont.)
Combustion Chamber History, PN 1133311-19, SN 021

Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Other	Repairs/Remarks
	Thrust Chamber Assy SN 477						
No	20.669/1	0.015	0.010	-	-	-	
No	221.677/2	0.011	0.015	-	-	-	
No	422.018/3	0.019	0.018	-	-	-	
No	622.861/4	0.019	0.019	-	-	-	
Yes	823.506/5	**	0.016	*	-	-	*Tubes 117 and 118 were repaired after test 305, leakage too small to measure.
No	1024.252/6	0.012	0.018	*	-	-	*Tubes 117 and 118 still leaking post-306, leakage too small to measure (IR 468447).
Yes	1224.722/7	0.018	0.018	*	-	-	*Same leaks as test -306 (IR 458748, Item 58).
No	1245.699/8	**	0.018	*	-	-	*No change in leakage from -307 (IR 458748, Item 65).
No	1245.699/8	**	**	*	-	-	No leak check performed post -309.
No	1446.060/9	**	0.015	2.0	-	-	*Tube leakage between 117, 118, and 119 (IR 469283).

but assumed to be in specification since
t engine.

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Table III--Time History of Discrepant Hardware (c

Engine Model LR87-AJ-11, Serial No. 15 (cont

Combustion Chamber History, PN 1133311-19, SN 02

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (c Tube-Flange	Tube
					Thrust Chamber Assy SN 477 (cont.)				
311	9-17-68	21.340	1	No	1467.400/10	0.018	0.020	*2.5	-
312	9-19-68	201.114	1	No	1668.415/11	0.020	0.020	*6.0	-
313	9-28-68	20.845	1	No	1689.359/12	0.020	0.012	*20.0	-
314	10-1-68	200.908	1	No	1890.267/13	0.020	0.020	*20.0	-
315	10-3-68	21.095	1	No	1911.362/14	0.018	0.021	*20.0	-
316	10-17-68	200.809	1	Yes	2112.171/5	**	0.021	*20.0	0

** Notes: Gap measurements not available but assumed to be in specification since there are no IRs written against engine.

ne History of Discrepant Hardware (cont.)
del LR87-AJ-11, Serial No. 15 (cont.)
mber History, PN 1133311-19, SN 021 (cont.)

	Inj-CC-Gap (max)		Leakage (cc/min)			
	Pre	Post	Tube-Flange	Tube	Other	Repairs/Remarks
rust Chamber Assy SN 477 (cont.)						
10	0.018	0.020	*2.5	-	-	*Tubes 116, 117, 118 and 119 (IR 468500).
11	0.020	0.020	*6.0	-	-	*Tubes 114, 116, 117, 118 and 119 (IR 468105).
12	0.020	0.012	*20.0	-	-	*Tubes 24 through 49, 58 through 65, and 118 (IR 468107).
13	0.020	0.020	*20.0	-	-	*No new tube leaks (IR 468111, Item 1).
14	0.018	0.021	*20.0	-	-	*No new tube leaks (IR 468118, Item 1). Cracks in 5 places in weld joint at shell to aft wire lock ring were repaired prior to test -316 (IR 468180).
5	**	0.021	*20.0	0	0	*No new tube leaks.

in specification since

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Combustion Chamber History, PN 1133311-19, SN 022

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Other
					Thrust Chamber Assy S/N 478					
301	6-3-68	20.669	2	No	20.668/1	0.015	0.013	-	-	-
302	6-6-68	201.008	2	No	221.677/2	0.011	0.018	-	-	-
303	6-14-68	200.341	2	No	422.018/3	0.019	0.018	-	-	-
304	6-18-68	200.843	2	No	622.861/4	0.023	0.023	-	-	-
305	6-24-68	200.645	2	Yes	823.506/5	**	0.017	*	-	-
306	7-26-68	200.746	2	No	1024.252/6	0.014	0.020	*	-	-
307	8-1-68	200.470	2	Yes	1224.722/7	0.025	0.022	*	-	-

** Note: Gap measurements not available but assumed to be in specification since there are no IRs written against engine.

Table III--Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 15 (cont.)
Combustion Chamber History, PN 1133311-[illegible], SN 022

rt	Accum. T/C	Inj-CC-Gap (max) Pre	Inj-CC-Gap (max) Post	Leakage (cc/min) Tube-Flange	Leakage (cc/min) Tube	Leakage (cc/min) Other	Repairs/Remarks
	Thrust Chamber Assy S/N 478						
	20.668/1	0.015	0.013	-	-	-	
	221.677/2	0.011	0.018	-	-	-	Flange erosion approximately 3/4 in. above where tube 6 joins flange (IR 458748, Item 20).
	422.018/3	0.019	0.018	-	-	-	
	622.861/4	0.023	0.023	-	-	-	
s	823.506/5	**	0.017	*	-	-	*Chamber repaired post 305 with leaks too small to measure after repair in tubes 45, 46, 51, 52 (IR 463774).
y	1024.252/6	0.014	0.020	*	-	-	*Tubes 45, 46, 51, 52, 58 through 62 and 14, 15, and 16 leaked post 306. Too small to measure (IR 468447, Item 2).
s	1224.722/7	0.025	0.022	*	-	-	Same leaks as test 306 (IR 458748, Items 56 and 57).

t assumed to be in specification since
engine.

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Table III --Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Combustion Chamber History, PN 1133311-19, SN 022 (cont.

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Oth
					Thrust Chamber Assy S/N 478 (cont.)					
308	8-14-68	20.977	2	No	1245.699/8	0.025	0.024	*	-	-
309	8-15-68	2.569	2	No	1248.268/9	**	0.024	*	-	-
310	8-16-68	200.361	2	No	1448.629/10	0.024	0.018	*	*	-
311	9-17-68	21.340	2	No	1469.969/11	0.018	0.023	*10.0	*	-
312	9-19-68	201.114	2	No	1671.083/12	0.023	0.023	30.0	*	-
313	9-28-68	20.245	2	No	1691.928/13	0.022	0.014	125.0	*	-
314	10-1-68	201.908	2	No	1892.836/14	0.024	0.024	80.0	-	-

** Note: Cap measurements not available but assumed to be in specification since there are no IRs written against engine.

e History of Discrepant Hardware (cont.)
del LR87-AJ-11, Serial No. 15 (cont.)
ber History, PN 1133311-19, SN 022 (cont.)

	Inj-CC-Gap (max)		Leakage (cc/min)			
	Pre	Post	Tube-Flange	Tube	Other	Repairs/Remarks
st Chamber Assy S/N 478 (cont.)						
	0.025	0.024	*	-	-	Tubes 14, 15, 16, 31, 32, 114, 115, 45, 46, 51, 52 and 58 through 66 leaking - unknown rate (IR 458748, Items 63 and 65).
	**	0.024	*	-	-	No leak check performed post -309 (IR 4578748, Item 69).
10	0.024	0.018	*	*	-	In addition to leakage noted on test 308, tube 25 has seepage leak (IR 469283).
11	0.018	0.023	*10.0	*	-	Additional tube leaks are 13, 17, 30 through 44, 67, 68. Also tube 25 has small crack (IR 468500).
12	0.023	0.023	30.0	*	-	No new tube leaks (IRs 468105 and 458748, Item 92).
13	0.022	0.014	125.0	*	-	No new tube leaks. Tube 25 is leaking at 50 cc/m and was repaired prior to test -314 (IRs 468107 and 458748, Item 98).
14	0.024	0.024	80.0	-	-	No new tube leaks (IRs 468111, Item 2 and 458748, Item 100).

in specification since

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Combustion Chamber History, PN 1133311-19, SN 022 (cont

Test	Date	Duration	S/A	Skirt	Accum. T/C	Inj-CC-Gap (max) Pre	Post	Leakage (cc/min) Tube-Flange	Tube	Ot
					Thrust Chamber Assy S/N 478 (cont.)					
315	10-3-68	21.095	2	No	1913.931/15	0.022	0.024	95.0	*	
316	10-17-68	200.809	2	Yes	2114.740/16	0.022	0.025	95.0	-	

* Note: Gap measurements not available but assumed to be in specification since there are no IRs written against engine.

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e III--Time History of Discrepant Hardware (cont.)
Engine Model LR87-AJ-11, Serial No. 15 (cont.)
stion Chamber History, PN 1133311-19, SN 022 (cont.)

Accum. T/C	Inj-CC-Gap (max) Pre	Inj-CC-Gap (max) Post	Leakage (cc/min) Tube-Flange	Leakage (cc/min) Tube	Leakage (cc/min) Other	Repairs/Remarks
Thrust Chamber Assy S/N 478 (cont.)						
1913.931/15	0.022	0.024	95.0	*	-	No new tube leaks. Crack in weld joint at shell to aft wire lock ring will be repaired for next test. External leakage from tube 123 V-band tack weld repaired prior to test -316 (IRs 468118 and 468180).
2114.740/16	0.022	0.025	95.0	-	-	Crack in vertical seam weld joining shell halves 180° from torus inlet crack is approximately 13 in. long (not detected previously).

ed to be in specification since

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Injector History, PN 1130409-129, SN 699

Test	Date	Duration	S/A	Skirt	Accum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7	
					Thrust Chamber Assy S/N 477								
301	6-3-68	20.669	1	No	20.669/1	-	-	-	-	-	-	-	
302	6-6-68	201.008	1	No	221.677/2	-	-	-	-	-	-	-	Foreign will be
303	6-14-68	200.341	1	No	422.018/3	-	-	-	-	-	-	-	Small pi rust lik Item 2).
304	6-18-68	200.843	1	No	622.861/4	-	-	-	-	-	1	-	White fo (IR 4386
305	6-24-68	200.645	1	Yes	823.506/5	2	1	2	1	-	1	-	Baffles on baffl
306	7-26-68	200.746	1	No	1024.252/6	-	-	-	-	-	-	-	
307	8-1-68	200.470	1	Yes	1224.722/7	-	-	-	-	-	-	-	
308	8-14-68	20.077	1	No	1245.699/8	-	-	-	-	-	-	-	
309	8-15-68	0.0	1	No	1245.699/8	-	-	-	-	-	-	-	
310	8-16-68	200.361	1	No	1446.060/9	-	-	-	-	-	-	-	
311	9-17-68	21.340	1	No	1467.400/10	-	-	-	-	-	-	-	
312	9-19-68	201.114	1	No	1668.514/11	-	-	-	-	-	-	-	
313	9-28-68	20.845	1	No	1689.359/12	1	-	-	-	-	-	-	
314	10-1-68	200.908	1	No	1890.267/13	3	1	1	1	1	1	-	Slot 1-1 baffle N
315	10-3-68	21.095	1	No	1911.362/14	3	1	1	1	1	1	-	Same as
316	10-17-68	200.809	1	Yes	2112.171/15	1*	1	2	1	1	2	1	*Baffle No. 5 s has slc

e History of Discrepant Hardware (cont.)

del LR87-AJ-11, Serial No. 15 (cont.)

or History, PN 1130409-129, SN 699

ccum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7	Repairs/Remarks
Thrust Chamber Assy S/N 477								
20.669/1	-	-	-	-	-	-	-	
21.677/2	-	-	-	-	-	-	-	Foreign material in baffle tips (1, 3, 6, and 7) will be back flushed (IR 438682).
22.018/3	-	-	-	-	-	-	-	Small piece of Teflon in tip of baffle 1; also rust like material in tip of baffle 6 (IR 438691, Item 2).
22.861/4	-	-	-	-	-	1	-	White foreign material noted in baffles 2 and 7 (IR 438692).
23.506/5	2	1	2	1	-	1	-	Baffles removed and replaced with 60°-70° bevel on baffle leg for improved weld (IR 458762).
24.252/6	-	-	-	-	-	-	-	
24.722/7	-	-	-	-	-	-	-	
45.699/8	-	-	-	-	-	-	-	
45.699/8	-	-	-	-	-	-	-	
46.060/9	-	-	-	-	-	-	-	
57.400/10	-	-	-	-	-	-	-	
58.514/11	-	-	-	-	-	-	-	
89.359/12	1	-	-	-	-	-	-	
90.267/13	3	1	1	1	1	1	-	Slot 1-1/4 in. long across holes on tips of baffle No. 5 (IR 468111, Item 4).
11.362/14	3	1	1	1	1	1	-	Same as test -314.
12.171/15	1*	1	2	1	1	2	1	*Baffle No. 1 now has one long crack. Baffle No. 5 slot now 2.5 in. long. Baffle No. 3 has slot 1 in. long (IR 458748, Item 119).

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Injector History, PN 1130409-129, SN 698

Test	Date	Duration	S/A	Skirt	Accum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7	
					Thrust Chamber Assy S/N 478								
301	6-3-68	20.669	2	No	20.668/1	-	-	-	-	-	-	-	
302	6-6-68	201.008	2	No	221.677/2	-	-	-	-	-	-	-	
303	6-14-68	200.341	2	No	422.018/3	-	-	-	-	-	-	-	3/8 in of baf No. 5
304	6-18-68	200.843	2	No	622.861/4	1	-	1	-	-	1	-	Foreig No. 1. No. 2,
305	6-24-68	200.645	2	Yes	823.506/5	3	1	1	-	1	2	2	Baffle on baf
306	7-26-68	200.746	2	No	1024.252/6	-	-	-	-	-	-	-	
307	8-1-68	200.470	2	Yes	1224.722/7	-	-	-	-	-	-	-	
308	8-14-68	20.977	2	No	1245.699/8	-	-	-	-	-	-	-	
309	8-15-68	2.569	2	No	1248.268/9	-	-	-	-	-	-	-	
310	8-16-68	200.361	2	No	1448.629/10	-	-	-	-	-	-	-	
311	9-17-68	21.340	2	No	1469.969/11	-	-	-	-	-	-	-	
312	9-19-68	201.114	2	No	1671.083/12	-	-	-	-	-	-	-	
313	9-20-68	20.895	2	No	1691.928/13	-	-	-	-	-	-	-	
314	10-1-68	200.908	2	No	1892.836/14	-	1	-	-	1	-	-	IR 46
315	10-3-68	21.095	2	No	1913.931/15	1	1	-	-	1	-	-	
316	10-17-68	200.809	2	Yes	2114.740/16	2	*	-	-	1	-	-	*Baff Baff Baff Item

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Table III--Time History of Discrepant Hardware (cont.)

Engine Model LR87-AJ-11, Serial No. 15 (cont.)

Injector History, PN 1130409-129, SN 698

Skirt	Accum. T/C	Baffle Weld Cracks 1	2	3	4	5	6	7	Repairs/Remarks
	Thrust Chamber Assy S/N 478								
No	20.668/1	-	-	-	-	-	-	-	
No	221.677/2	-	-	-	-	-	-	-	
No	422.018/3	-	-	-	-	-	-	-	3/8 in. long strip of foreign material in tip of baffle No. 1. Rust like material in tip of No. 5 baffle (IR 438691).
No	622.861/4	1	-	1	-	-	1	-	Foreign material from test 303 still in baffle No. 1. Foreign material also noted in baffles No. 2, 4, 5, and 6 (IR 438692).
Yes	823.506/5	3	1	1	-	1	2	2	Baffles removed and replaced with 60 to 70° bevel on baffle leg for improved weld (IR 458761).
No	1024.252/6	-	-	-	-	-	-	-	
Yes	1224.722/7	-	-	-	-	-	-	-	
No	1245.699/8	-	-	-	-	-	-	-	
No	1248.268/9	-	-	-	-	-	-	-	
No	1448.629/10	-	-	-	-	-	-	-	
No	1469.969/11	-	-	-	-	-	-	-	
No	1671.083/12	-	-	-	-	-	-	-	
No	1691.928/13	-	-	-	-	-	-	-	
No	1892.836/14	-	1	-	-	1	-	-	IR 468111, Item 4.
No	1913.931/15	1	1	-	-	1	-	-	
Yes	2114.740/16	2	*	-	-	1	-	-	*Baffle No. 2 crack no longer shows. Baffle No. 3 has approximately 1 in. slot. Baffle No. 5 has 1.0 in. slot (IR 458748, Item 119).

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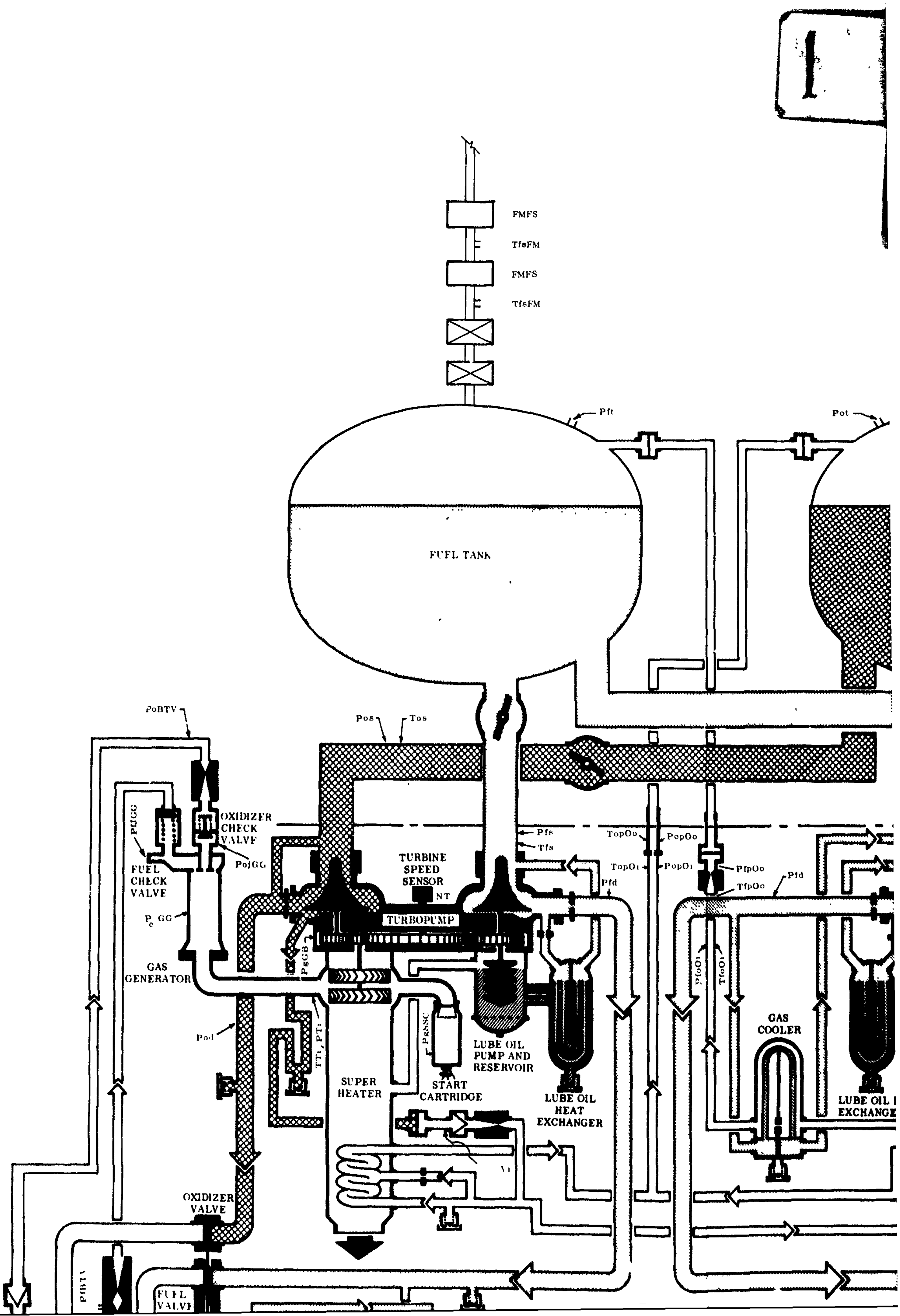
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FUEL CHECK VALVE
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P_c GG
GAS GENERATOR
Pfs
Tfs
TopOo
PopOo
TopOi
PopOi
PfpOo
TfpOo
Pfd
TURBINE SPEED SENSOR
NT
TURBOPUMP
PgGB
TTi, PTi
PsSC
Pod
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SUPER HEATER
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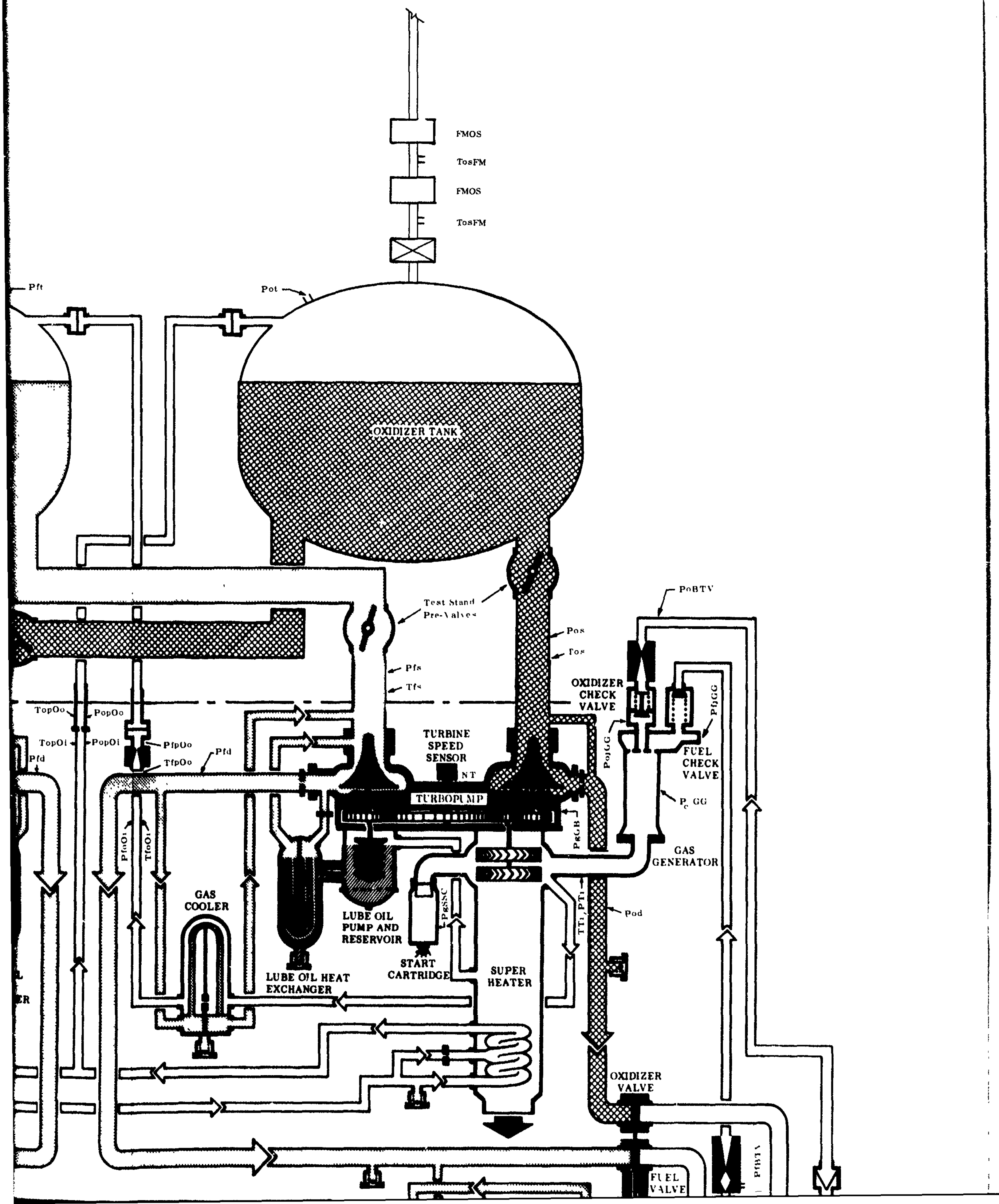
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PfjGG
PojGG
FUEL CHECK VALVE
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PopOo
TopOi
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TURBOPUMP
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PgGB
GAS GENERATOR
PfoOi
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GAS COOLER
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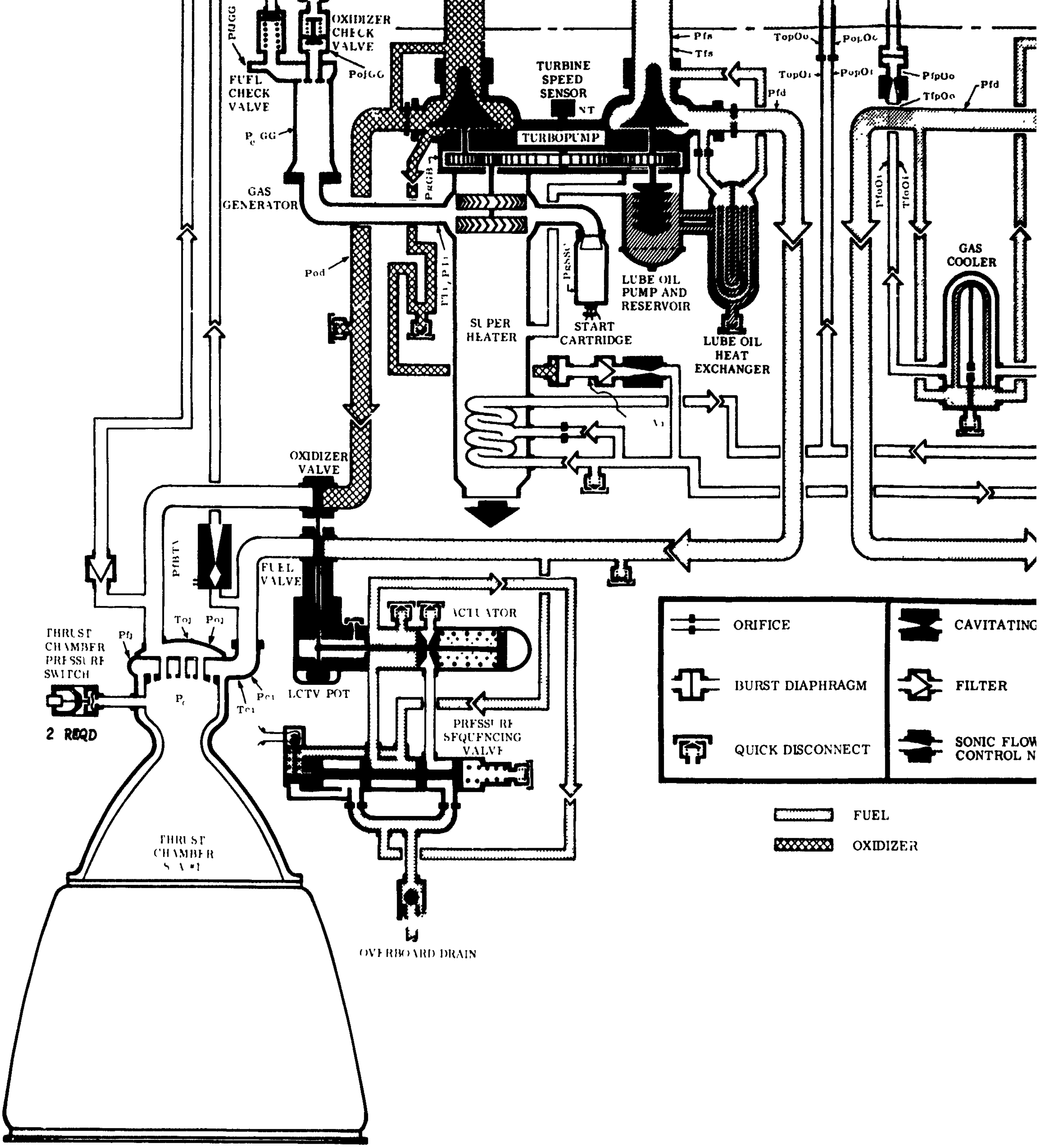

Figure 16 -- Instrumentation Loca

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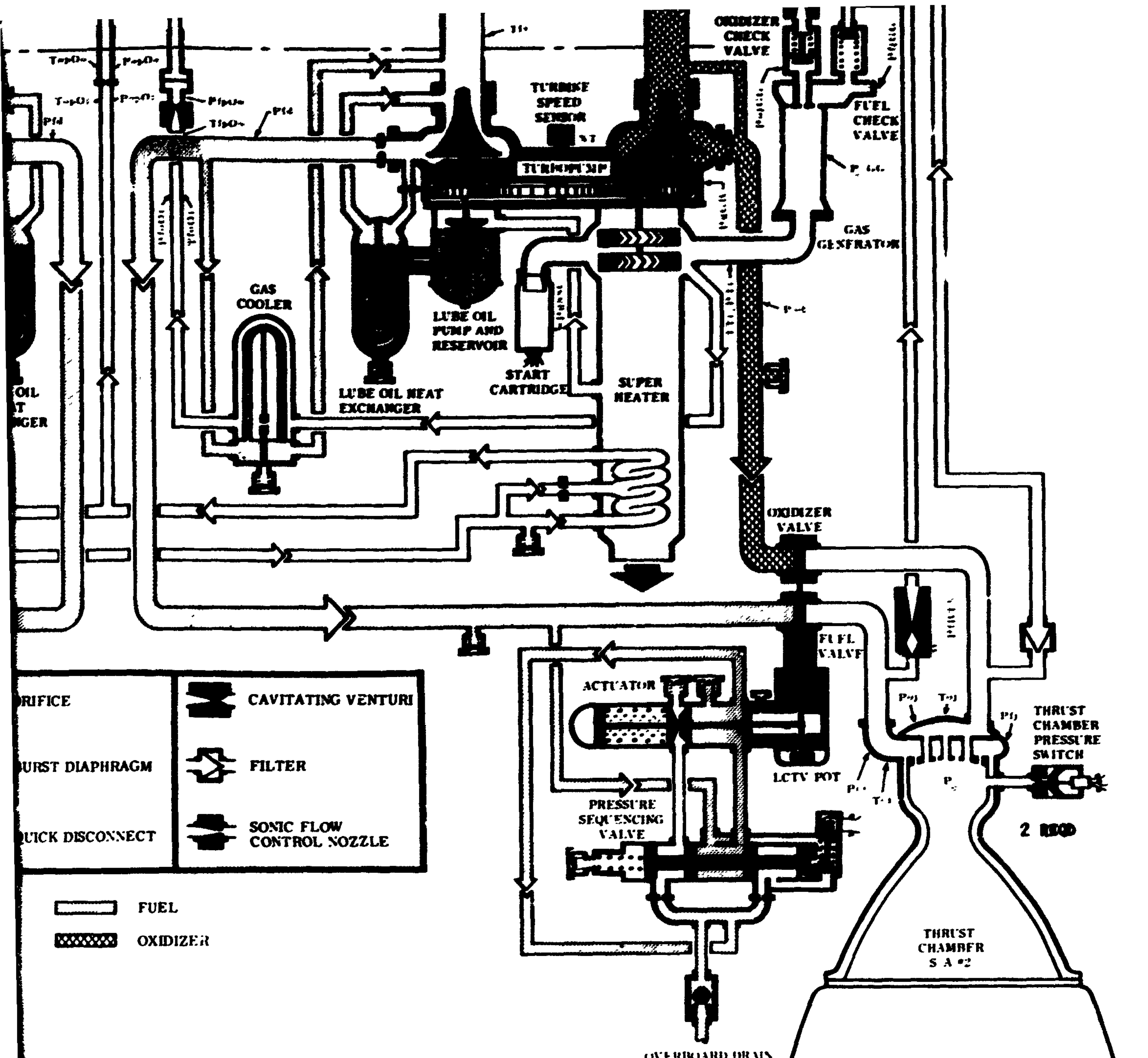

e 16 -- Instrumentation Locations

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